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PREFACE

The volumes of the International Library of Technology are made up of Instruction Papers, or Sections, comprising the various courses of instruction for students of the International Correspondence Schools. The original manuscript for each Instruction Paper is prepared by a person thoroughly qualified, both technically and by experience, to write with authority on his subject. In many cases the writer is regularly employed elsewhere in practical work and writes for us during spare time. The manuscripts are then carefully edited to make them suitable for correspondence work.

The only qualification for enrolment as a student in these Schools is the ability to read English and to write intelligibly the answers to the Examination Questions. Hence, our students are of all grades of education, and our Instruction Papers are, therefore, written in the simplest possible language so as to make them readily understood by all students. If technical expressions are essential to a thorough understanding of the subject, they are clearly explained when first introduced.

The great majority of our students wish to prepare themselves for advancement in their vocations or to qualify for other and more congenial occupations. Their time for study is usually after the day's work is done and is limited to a few hours each day. Therefore, every effort is made to give them practical and accurate information in clear, concise form, and to make this information include all of the essentials but none of the non-essentials. To effect this result derivations of rules and formulas are usually omitted, but thorough and complete instructions are given regarding how, when, and under what conditions any particular rule, formula, or process should be applied. Whenever possible one or more examples, such as would be likely to arise in actual practice, together with their solutions, are given for illustration.

As the best way to make a statement, explanation, or description clear is to give a picture or a diagram in connection with it, illustrations are very freely used. These illustrations are especially made by our own Illustrating Department in order to adapt them fully to the requirements of the text. Projection drawings, sectional drawings, outline drawings, perspective drawings, partly shaded or full shaded, are employed, according to which will best produce the desired result. Half-tone engravings are used only in those cases where the general effect is desired rather than the actual details.

In the table of contents that immediately follows are given the titles of the Sections included in this volume, and under each title is listed the main topics discussed. At the end of the volume will be found a complete index, so that quick reference can be made to any subject treated.

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CONTENTS

DRILLING

	Section	*Page*
Parts and Uses of Drilling Machines	13	1
Drilling Tools	13	6
Annular Cutters	13	14
Lubrication of Drills	13	20
Reamers	13	21
Countersinks	13	28
Counterbores	13	30
Spot-Facing Operations	13	34
Holding Devices for Drills	13	36
Holding Work for Drilling	13	44
Drilling Machines	14	1
Drilling, Reaming, and Tapping	14	20
Countersinking, Counterboring, Facing, and Center Drilling	14	29
Lubricants	14	31
Drill Grinding	14	31
Drilling Jigs and Fixtures	14	34
Cutting Speeds and Feeds	14	46
Tables of Data for Drilling	14	49

LATHE WORK

Lathes and Lathe Attachments	15	1
Engine Lathe	15	1
Lathe for Heavy Work	15	23
Lathe Chucks	15	29
Mandrels	15	41
Theory of Cutting Tools	[illegible]	1
Forms of Cutting Tools	[illegible]	[illegible]
Tool Grinding	16	[illegible]

Lathe Work—*Continued*	*Section*	*Page*
Chucking Tools	16	33
Types of Boring Bars	16	39
Chattering	16	41
Cutting Speeds and Feeds	17	1
Cylindrical Turning	17	14
Fitting Cylindrical Work	17	31
Boring Operations	17	40
Taper Turning	18	1
Radial Facing	18	13
Turning Long Work	18	15
Turning with a Rotating Tool	18	22
Finishing Lathe Work	18	30
Errors in Lathe Work	18	35
Screw Threads	19	1
Cutting Screw Threads	19	24
Tapping	19	60
Turret Lathe	20	1
Screw Machines	20	2
Toolmakers' Lathe	20	42
Bench Lathes	20	44
Plain Taper-Turning Lathe	20	46
Gap Lathe	20	49
Two-Spindle Lathe	20	49
Axle Lathe	20	51
Wheel Lathe	20	53
Pulley Lathe	20	54
Hand Lathe, or Speed Lathe	20	54
Pipe-Cutting Machine	20	57
BORING-MILL WORK		
Classes of Boring Machines	21	1
Vertical Boring-Mill Work	21	2
Horizontal Boring-Mill Work	21	13
Horizontal Floor Mills	21	24
Cylinder Boring	21	28
Boring Spherical Bearings	21	32
Boring Fixtures	21	34

WORKING CHILLED IRON *Section* *Page*
Chilled Iron 22 1
Turning Chilled Iron 22 3
Grinding Chilled Rolls 22 29
Planing Chilled Iron 22 33
Drilling Chilled Iron 22 36

BENCH, VISE, AND FLOOR WORK
Bench and Vise Work 23 1
Tools and Fixtures Employed 23 1
Chipping 23 24
Filing 23 32
Grading of Files 23 35
Filing Machines 23 50
Scraping 24 1
Broaching 24 8
Fitting Keys 24 12
Drilling 24 14
Reaming 24 21
Thread Cutting 24 24
Laying Out 24 31

ERECTING
Introduction 25 1
Pinch Bars, Rollers, and Blocking Devices . 25 2
Foundations, Floors, and Pits 25 12
Hoists and Trucks 25 21
Derricks 25 34
Ropes 25 39
Fitting of Parts 26 1
Inspection of Work 26 10
Erection of Large Wheels 26 15
Erection of Lathes and Planers 26 18
Engine Erection 26 36

DRILLING
(PART 1)

DRILLING OPERATIONS AND TOOLS

PARTS AND USES OF DRILLING MACHINE

CONSTRUCTION OF DRILLING MACHINE

1. The term **drilling,** as used in the machine shop, denotes the operation of sinking circular holes in solid bodies with a rotating tool called a *drill.* The drill is held and turned by a drilling machine, which, when of the upright type, is called a *drill press*, or *driller*. There are, however, a large number of other types of drilling machines, which have special names depending on their forms or on the operations for which they are to be used.

2. Essential Parts of Drilling Machine.—The modern drilling machine consists of a bed, or frame, carrying a rotating spindle at the lower end of which is a socket for the tool or the tool holder, a table on which the work is supported, and a feed-motion by which the tool is fed into the work. A type of drilling machine that is largely used for light and medium work is shown in Fig. 1, and one or more machines of this general type may be found in nearly every machine shop. There are simpler forms of drilling machines, but that shown in the illustration has all of the main parts.

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3. Driving Gear.—The spindle *a*, Fig. 1, is driven by means of a pair of bevel gears *b* and a belt running on a pair of cone pulleys *c*. The four steps on the cones furnish four different speeds, any one of which may be obtained by simply throwing the belt to the desired step. A belt running from the driving pulleys *d* and *e* to a countershaft transmits the power to the drill. One of these driving pulleys is keyed rigidly to the shaft and the other runs loose on the shaft. When the belt is on the loose pulley, the drill stands still. To start the drill, the

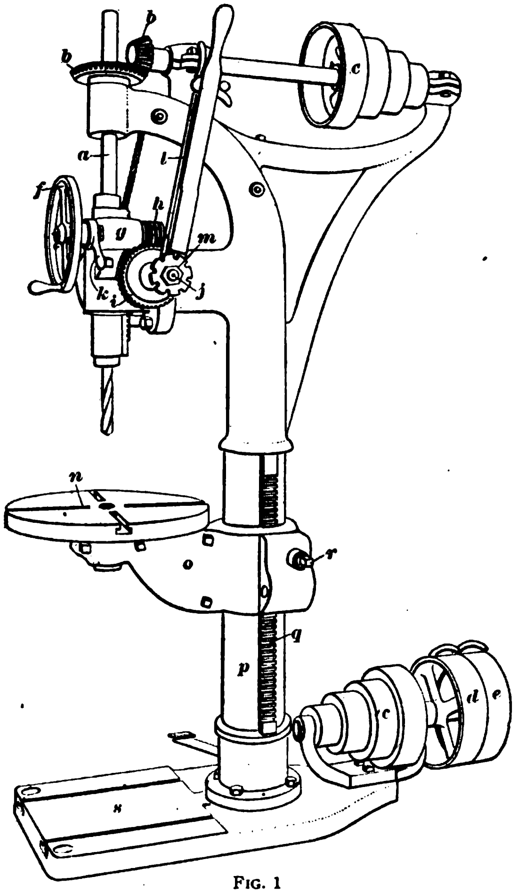


FIG. 1

belt is shifted from the loose pulley to the tight pulley, and thus transmits the power to the lower cone pulley *c* and to the drill.

4. **Feed-Motion.**—The spindle of the machine shown in Fig. 1 may be fed downwards by turning the hand wheel *f*, which is keyed to one end of a shaft that has its bearing in the box *g*. At the other end of this shaft is a worm *h* that meshes with a worm-wheel *i* fixed on the lever shaft *j*. Heavy pressure can be exerted at the end of the drill by turning the hand wheel; consequently, the feeding is done by use of the hand wheel when the machine is doing heavy work. If lighter work is to be done, the lever feed is used, in which case the hand-wheel feed must be put out of action by moving the short lever *k*. The feed-shaft *j* may then be moved by the lever *l*, which has a spring latch that can be lifted and dropped into the notches in the wheel *m* fixed to the feed-shaft. The spring latch is moved by means of a handle at the upper end of the lever *l*.

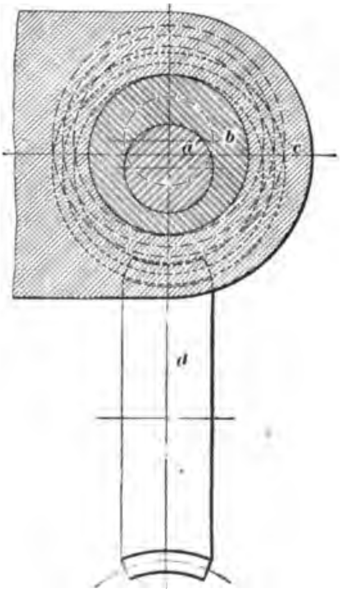


FIG. 2

5. The means by which the worm *h*, Fig. 1, is thrown out of mesh with the worm-gear *i* is simple. In the box *g* is an eccentric bushing in which the shaft of the worm and the hand wheel is carried. The eccentric bushing may be rotated by moving the lever *k*, and the worm-shaft is thus moved upwards, carrying the worm out of mesh with the worm-gear. This action may be made clearer by reference to the section in Fig. 2, in which *a* represents the shaft of the hand wheel and the worm, passing through the eccentric bushing *b* carried by the box *c*, and *d* is the worm-gear. When the eccentric bushing is in the position shown, the worm is in that indicated by the dotted circles, and

is engaged with the worm-gear; but when the bushing is turned half-way around, the shaft *a* and the worm are brought to the positions indicated by the dot-and-dash lines, and the worm is thrown out of mesh with the worm-gear.

6. Table of Drilling Machine.—The drilling-machine table *n*, Fig. 1, is supported on the arm *o* and may be rotated about its center, and both the arm and the table may be swung on the column *p*. The table may be raised or lowered by a gear that engages with the rack *q* and that is turned by a worm and a worm-gear operated by a wrench or crank applied to the square *r*. The drill foot *s* is used as an auxiliary table on which work that is too large for the table *n* may be placed.

USES OF DRILLING MACHINE

7. The drilling machine was brought into use for the purpose of sinking circular holes in solid bodies; but its use has been extended so that it is now employed also for finishing operations such as reaming, countersinking, counterboring, center drilling, tapping, spot facing, and many turning operations formerly done on the lathe and the boring mill.

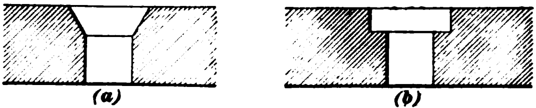

(*a*) (*b*)

FIG. 3

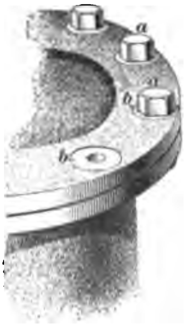


FIG. 4

8. The varying hardness of the metal, blowholes in castings, and slight imperfections in the form of the tool tend to make a drilled hole imperfect. Sometimes the hole is not quite straight, or it may not be quite round, or the surface may be rough, so that an additional operation may be needed to bring it to correct shape and size. The operation of running a reamer through a drilled hole to straighten the hole, smooth it, or bring it to size, is called **reaming.**

9. **Countersinking** is the operation of enlarging the end of a hole conically as shown in Fig. 3 (*a*), so as to take the tapered head of a screw or a machine part.

10. **Counterboring** is the operation of enlarging the end of a hole, as shown in Fig. 3 (*b*), so that the sides of the enlarged part are carried straight down and a flat shoulder is formed at the bottom.

11. **Spot facing** is the operation of finishing a piece of work for only a short distance around the end of a drilled hole, to form a smooth bearing surface for the head or the nut of a bolt, or for the hub of an adjoining part. An example of spot facing is shown in Fig. 4, in which, to form flat bearing surfaces for the heads *a* of the bolts, the spots *b* are faced on the cylinder head.

12. **Facing** is the operation of finishing the ends of a hub, or of a similar part, by a flat revolving cutter held in a bar. For example, the rocker-arm in Fig. 5 has its end surfaces *a* faced to form bearing surfaces for the collar *b* and the washer *c*.

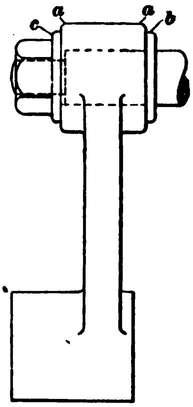


FIG. 5

13. **Center drilling** is the operation of forming a center hole in a piece of work for a lathe, by the use of a drill and a center reamer.

14. **Tapping** is the operation of cutting an internal screw thread in a piece of metal by the use of a tap. One form of tap, or tool used for this operation, is shown in Fig. 6. It consists of a tapering screw of hardened steel that is grooved, or fluted, to give a series of cutting teeth that form the thread when the tap is turned in the hole.

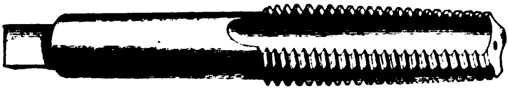


FIG. 6

DRILLING TOOLS

CLASSIFICATION AND MAIN FEATURES

15. The drill is one of the most extensively used tools found in the machine shop and is made in a number of different forms. These various forms may be divided into two main classes, namely, *flat drills* and *twist drills*.

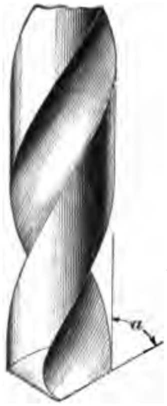


FIG. 7

16. Main Features of Drills.—Every drill, no matter of what kind, must have three main features. First, there must be one or more cutting edges that remove the material either by scraping or by cutting. Second, there must be a central leading point about which the cutting edges revolve and which guides the drill through the material. This is obtained by tapering the cutting edges toward the center, as shown in Fig. 7. The angle *a* of this taper varies for different classes of work, but for ordinary drilling it is made between 50° and 60°. The Morse Twist Drill Company recommends 59°, while Wm. Sellers & Co. recommend 52°. Third, there must be a clearance back of the cutting edge. Fig. 8 represents the point of a flat drill, in which *b* is the *clearance angle*, sometimes called the *angle of relief*. This angle should be large enough so that the stock back of the cutting edge will not bear against the work.

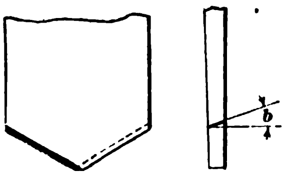


FIG. 8

FLAT DRILLS

17. Form of Drill Point.—The simplest and most cheaply made machine-shop drill is the ordinary flat drill shown in Fig. 9. When rightly formed, this type of drill does very good work. It is, however, a hand-made tool and is often so poorly formed and so imperfectly ground that its work is not satisfactory. If a drill is to cut equally on both sides and form a smooth, round hole, having the same diameter as the drill, five conditions are necessary: the point must be in the center, the cutting edges must make equal angles with the center line, and must be of the same length and have equal clearance angles, and the sides should be parallel.

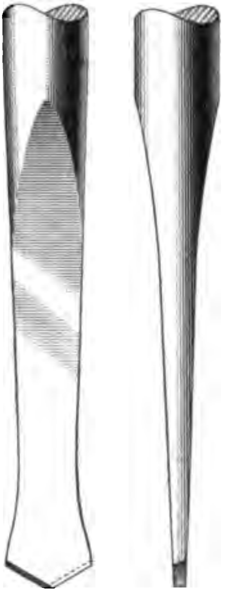


FIG. 9

18. Results of Improperly Formed Drills.—It is not sufficient to have the point in the center of the drill, because different angles of the cutting edges will cause the drill to cut on one side only, as shown in Fig. 10 (*a*), thus throwing twice the intended depth of cut on the one cutting edge. It also causes a crowding against one side, and a tendency to throw the center of the drill out of its correct position. The angles that the cutting edges make with the center line may be equal, but if the lengths of the cutting edges are not equal, the hole will be larger than the drill, as shown in (*b*). The outer end of the long side of the cutting edge will then do double duty, which will soon dull it, cause crowding, and make a rough hole.

19. When both the angles with the center line and the lengths of the cutting edges are unequal, the hole will be larger than the drill, and the effect will be as shown in Fig. 10 (*c*); that is, all the work will be done by the short side and the outer end of the long side. Unequal clearance angles will cause one side to cut more freely than the other, thus distributing the work unequally. Under a given pressure, the side with the greater clearance angle tends to take a deeper cut than the other, while there is less metal to support its cutting edge. This edge wears away more rapidly than the other, resulting in unsatisfactory working conditions.

20. Advantages of Thin Drill Point.—In the flat-drill point shown in Fig. 11, the cutting edges *a b* and *c d* are of equal lengths, the clearance angles are equal, and the edge *b d* at the point of the drill is at right angles to the center line of the drill.

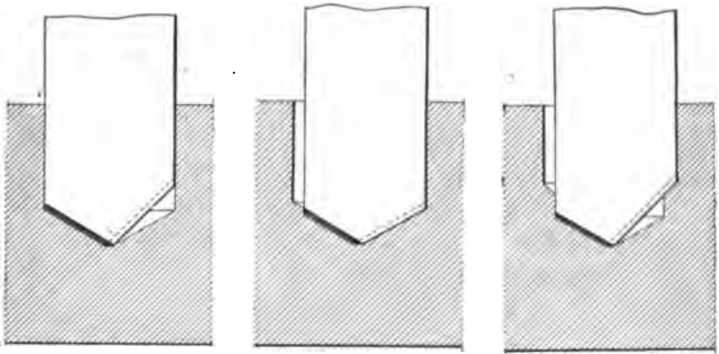

(*a*) (*b*) (*c*)

FIG. 10

When the drill turns, the edge *b d* acts as a scraping edge instead of a cutting edge, and the pressure required to force it through the metal at the rate at which the drill should cut is very great compared with the pressure required on the cutting edges. The scraping edge wears rapidly, and as it grows dull the pressure required to feed the drill becomes greater. To reduce this pressure, the scraping edge should be shortened. Shortening is done by making the drill thin at the point; however, it must not be too thin, or the cutting edges will not be supported sufficiently and will break, and the drill will need to be reground frequently.

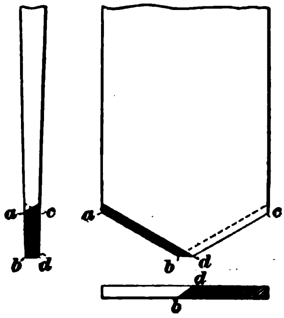


FIG. 11

21. Grooved Drill Point. Sometimes grooves are formed in the end of the drill, as shown in Fig. 12, thus providing curved cutting edges, that, when properly shaped, remove most of the scraping edge. This practice, however, tends to weaken the inner ends of the cutting edges by removing the supporting metal, and it is generally thought to be better simply to make the end of the drill as thin as practicable.

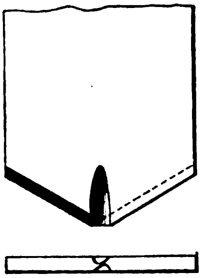


FIG. 12

22. Parallel Sides for Drills.—Flat drills, to give the best results, should have the sides *a b*, Fig. 13 (*a*), parallel for a distance of ½ inch or more above the cutting edges. This parallel part should be rounded to fit the circumference of the hole. Drills are often used with the corners projecting beyond the body, as shown in (*b*), and with the sides beveled, as shown in (*c*). Drills formed in this way make ragged holes, and when there are soft or hard spots or blowholes in the material drilled, they run off to one side, making holes that are not straight, round, nor smooth. The simple precaution of making the sides parallel for a short distance and rounding the edges to fit the hole, as shown in (*d*), will, when the point is rightly formed, obviate this difficulty almost entirely.

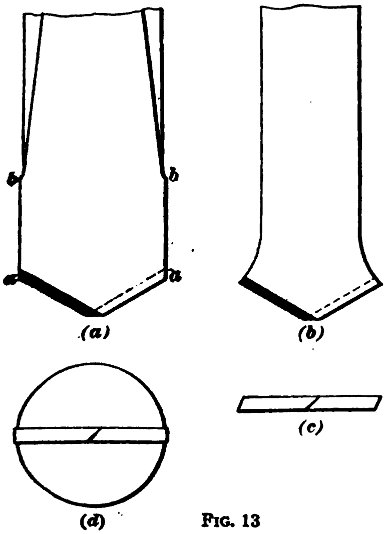


FIG. 13

23. Drill Shank.—The part of the drill between the cutting part and the upper end is called the *shank*. It should be somewhat smaller than the hole, in order to work freely in it. In the case of comparatively shallow holes, the flat part should extend to a point high enough so that the cuttings or chips can work out. The shank should be round, as the corners of any angular section draw the chips under them and clog the drill. Even with a round shank and a perfectly formed drill, there will be more or less clogging in a deep hole, and it is often necessary to back out the drill and remove the cuttings.

24. **Lipped Drill.**—The ordinary flat drill has the front face, or the face above the cutting edge, either at right angles to the direction of motion, as in Fig. 14 (*a*), or else slanted forwards a little, as in (*b*). If the face is slanted backwards just above the cutting edge, the drill will cut more easily. The tool is then said to have *front rake*. One way of doing this is to grind a groove just above the cutting edge, as shown in Fig. 15 (*a*). A section along the line *c d* is shown in (*b*). Another way is to form the tool with a lip at the cutting edge, as in (*c*). A section of this drill on the line *e f* is shown in (*d*). In each of the drills shown in (*a*) and (*c*), care must be taken to leave enough metal back of the cutting edge to withstand the cutting strain.

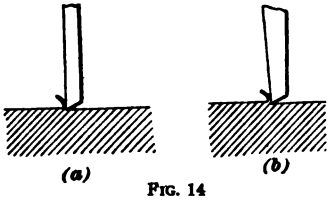


Fig. 14

-25. **Twisted Flat Drills.**—One disadvantage of lipped drills is that grinding reduces the lip, and necessitates frequent reforging, or dressing. This objection may be overcome by twisting the end of the drill into a spiral, as shown in Fig. 15 (*e*). In this way, the same angles of the cutting edges may be obtained, but the shape is not altered by grinding, until the entire spiral is ground away. The spiral also assists in carrying the cuttings away from the drill point.

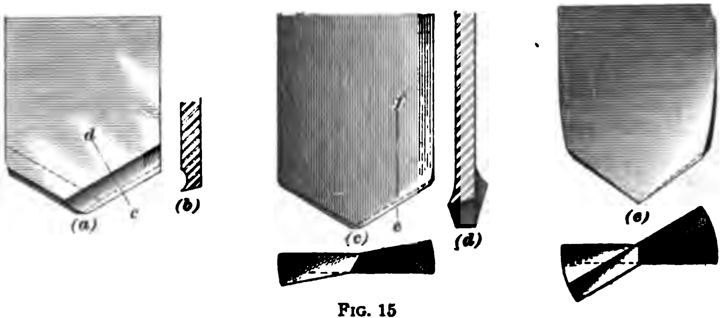


Fig. 15

TWIST DRILLS

26. Ordinary Twist Drill.—The twist drill is in universal use because it removes its cuttings, requires no reforging, and can be resharpened repeatedly by a simple grinding operation. Fig. 16 (*a*) illustrates an ordinary commercial drill of this type. It is generally made from round stock, the spiral flutes being cut with a milling cutter, or else formed by rolling or forging. The surface between the flutes is backed off slightly from near the cutting edges *a*, Fig. 17 (*a*), to the backs *b* of the flutes, leaving only narrow strips *a c* the full diameter of the drill. This is done to reduce the bearing surface on the side of the hole, but enough surface is left to form a perfect guide, owing to the fact that the bearing *a c* runs in a spiral around the drill. In some drills a narrow bearing strip is left, as shown in Fig. 16 (*b*), the clearance being cut away, concentric with the bearing surface, as illustrated in Fig. 17 (*b*).

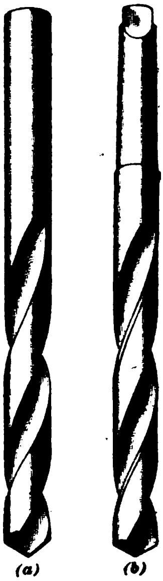


Fig. 16

Twist drills are also made with three or four grooves or lips, and are sometimes called *reamers*. They are similar to the ordinary twist drill in most of their details. The cutting end, however, is left square and is beveled for one-quarter or one-third of the diameter of the drill to form cutting edges. These drills will not cut from the solid, but are used for reaming cored holes or for reaming holes made by a flat or twist drill. They are used for jigwork in the drilling machine, and largely for turret-lathe work.

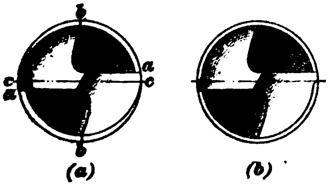


Fig. 17

27. Twisted Drill.—The twisted drill, shown in Fig. 18, is a form that resembles the twist drill. It is made from flat stock or from stock that is rolled thinner at the middle than at the edges, and that is then twisted to the required form and ground. The shank is usually flat, but it may be made round, like that of a twist drill. The advantages claimed for the twisted drill are that it requires little stock in manufacture, has a large space for chips, and may be hardened and tempered more easily than the twist drill. It is made from rolled stock, and the compressing of the material during the rolling process increases its strength, so that the drill is less likely to split up the center.

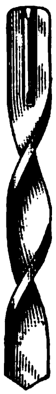


FIG. 18

STRAIGHT-FLUTED, SLOT, AND TEAT DRILLS

28. Straight-Fluted Drill.—The straight-fluted drill, shown in Fig. 19, is best suited for drilling thin plates and brass. There is a tendency for a twist drill to plunge forwards as it comes through the piece being drilled. By making the flutes of the drill straight instead of spiral, this tendency is overcome.

29. Forms of Slot Drills.—In drilling machines in which slides that feed perpendicular to the center line of the spindle are provided, slot, or keyway, drills are often used. These are made in a number of different forms. In Fig. 20 (*a*), (*b*), (*c*), and (*d*) are shown four different kinds, all of which are quite satisfactory in metal of uniform hardness. In sinking these drills into the metal, holes are formed as shown in (*e*), (*f*), (*g*), and (*h*). The central cores in (*e*) and (*f*) form guides for the drill, which, in metal of varying hardness, have been found of great advantage.

FIG. 19

30. Use of Slot Drills.—Slot drills are used largely in forming keyways, or slots, in shafts. They are sunk into the metal to a sufficient depth for a longitudinal cut and are then fed lengthwise along the shaft, thus cutting out the metal to this depth throughout the entire length of the slot. The drill is then lowered enough to furnish another longitudinal cut and the operation is repeated until the required depth is obtained. The drills shown in Fig. 20 (*c*) and (*d*) may be used in squaring the bottoms of holes made by an ordinary twist drill at the ends of keyways to be planed or chipped.

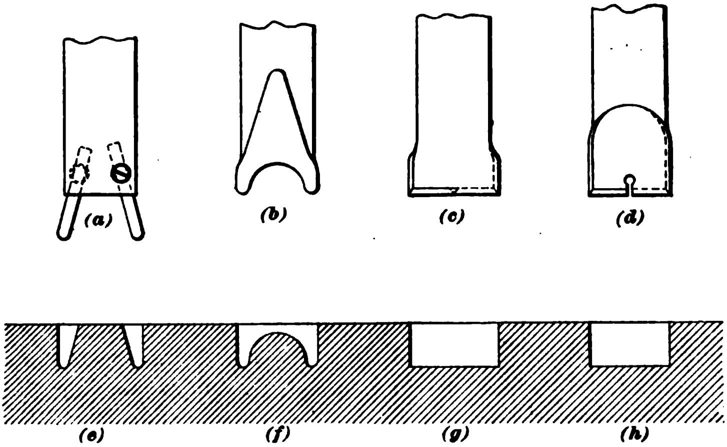


Fig. 20

31. Teat Drill.—The teat drill is made like an ordinary flat drill, except that its cutting edges are at right angles to the center line of the drill, as shown in Fig. 21. Instead of the scraping edge found in the flat drill, however, there is a teat *a* that has cutting edges on opposite sides and that serves to guide the drill. The teat drill is largely used for flattening the bottoms of holes made with ordinary drills, but sometimes it is used to drill a hole to the entire depth. It is very suitable for drilling holes in sheet metal, particularly in brass and copper. The teat is a four-sided pyramid, and the corners nearest the cutting edges of the drill are in the lead, thus providing good cutting edges for the point, and giving it proper clearance.

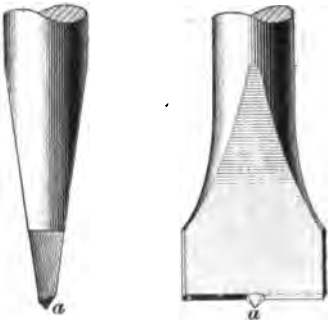


Fig. 21

ANNULAR CUTTERS

32. Single-Tool and Double-Tool Cutters.—A form of annular cutter that is used very generally for removing large bodies of metal and cutting large holes in boiler plates, rod ends, etc., is shown in Fig. 22. The tool *a* is a right-angled cutting-off tool, with the proper side clearance to clear the circular sides of the hole. A hole *c* is first drilled for the guide pin *b*, after which the stock around the hole *c* is removed as a washer with a hole in the center. Sometimes two tools are used, one on each side of the center, as shown in Fig. 23. This balances the side thrust on the center pin *b* and reduces it to a minimum, besides doubling the capacity of the tool.

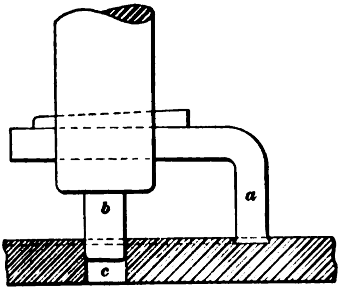


FIG. 22

33. Hollow and Butt Mills.—The hollow mill, shown in Fig. 24, is a tool that is occasionally used in a drilling machine to form a turned or finished projection on a machine part. The center is hollowed out to the diameter of the required boss or projection, and the depth of this hollow center is great enough to give the proper length of the projection. Four cutting edges are formed at the bottom of the tool.

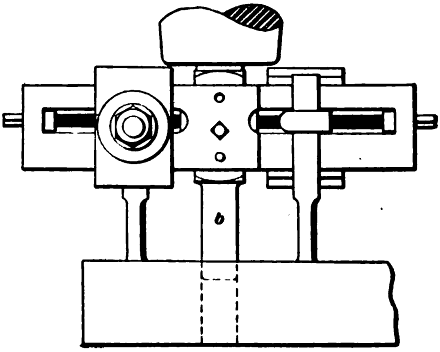


FIG. 23

The butt mill differs from the hollow mill in that it is made solid instead of hollow, has more teeth, and has the latter cut to only about half the depth of the teeth on the hollow mill. It is used to flatten the conical bottoms of holes and to remove the metal between adjoining holes drilled in a row. When used for the latter purpose, it

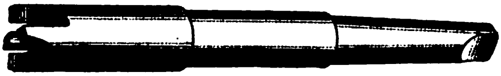


FIG. 24

is usually held and driven by a drill chuck and guided by a drilling jig.

34. Hubbing Tool.—A very useful form of tool,,known as a hubbing tool, is shown in Fig. 25. A hub *a* of the piece *b* is to be finished as shown at *c*. The tool with which this is done consists of a center bar *d*, which fits the bore of the hub, and a tool *e* supported on the arm *f*. As the tool is rotated about the center of the pin, it cuts a perfect circle.

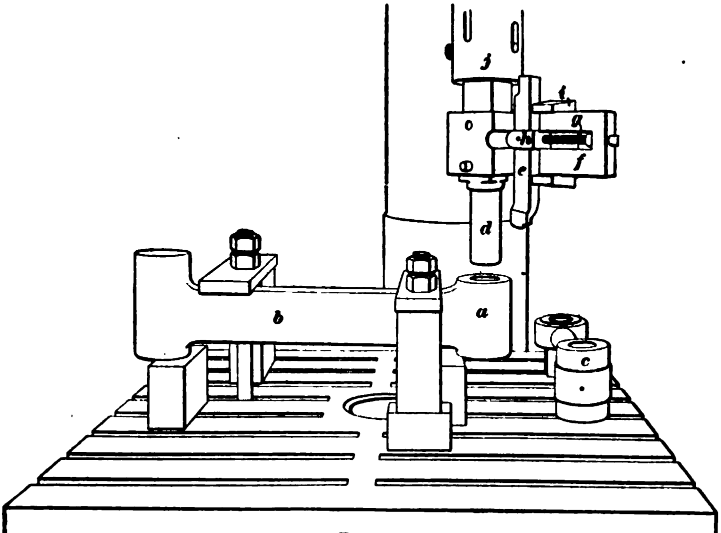
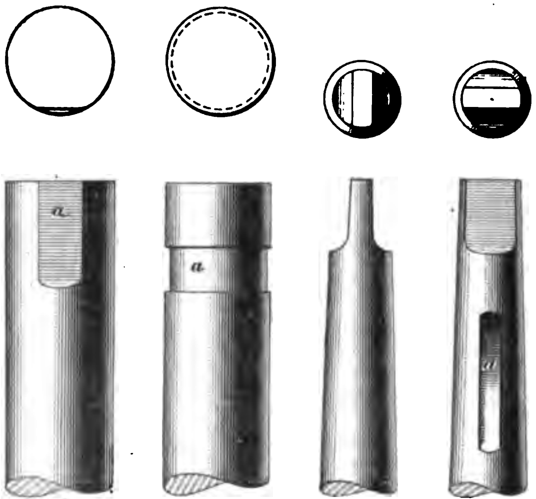


FIG. 25

The device is attached to the spindle *j* of a heavy drilling machine, the work being fastened on the table. The radius at which the tool cuts is regulated by the adjusting screw *g* and a clamp *h* and *i*.

DRILL SHANKS

35. Straight Shank.—On ordinary flat drills, the forms of shanks shown in Fig. 26 (*a*) and (*b*) are quite commonly used. In (*a*) the shank is straight and slightly flattened at *a* to furnish a good bearing for the setscrew. The end of the screw often cuts a burr at the bearing point, which prevents the easy removal of the drill, and to avoid this the shank may be turned down slightly at the bearing point of the screw, as shown at *a* in view (*b*). The shoulder also prevents the tool from dropping out of the socket when the screw becomes slightly loose.



(*a*) (*b*) (*c*) (*d*)

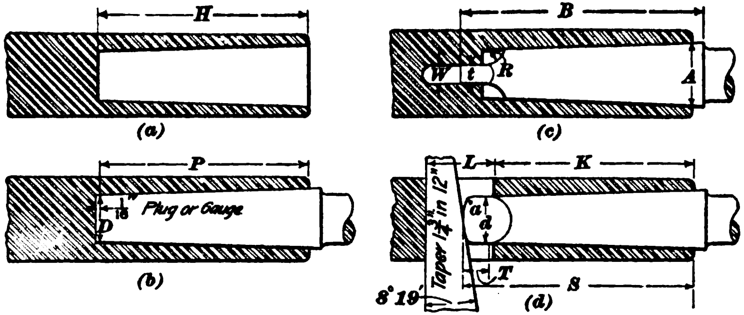
FIG. 26

36. Taper Shank.—The taper shank, shown in Fig. 26 (*c*) and (*d*), is used because it centers the drill, gives considerable friction in the socket to help to drive the drill, and is easily removed from the socket. The taper is made slight enough to cause the socket to grip the shank and prevent the drill from dropping out of its own weight. The flattened end, called the *tang*, helps to turn the drill, as it fits a corresponding hole in the socket. Several different tapers are used by different makers of drills, the most common being the Morse taper, which is about

TABLE I

MORSE TAPERS

(From Morse Twist Drill and Machine Company)



Number of Taper	Diameter of Plug at Small End	Diameter at End of Socket	Standard Plug Depth	Whole Length of Shank	Depth of Hole	End of Socket to Keyway	Length of Keyway	Width of Keyway	Length of Tongue	Diameter of Tongue	Thickness of Tongue	Radius of Mill for Tongue	Radius of Tongue	Shank Depth	Taper per Foot	Taper per Inch	Number of Key
	D	A	P	B	H	K	L	W	T	d	t	R	a	S			
0	.252	.356	2	$2\frac{11}{32}$	$2\frac{1}{32}$	$1\frac{15}{16}$	$\frac{9}{16}$	.160	$\frac{1}{4}$	.235	$\frac{5}{32}$	$\frac{5}{32}$	.04	$2\frac{7}{32}$	.625	.05208	0
1	.369	.475	$2\frac{1}{8}$	$2\frac{9}{16}$	$2\frac{3}{16}$	$2\frac{1}{16}$	$\frac{3}{4}$	.213	$\frac{3}{8}$	.343	$\frac{13}{64}$	$\frac{3}{16}$	.05	$2\frac{7}{16}$	.600	.05000	1
2	.572	.700	$2\frac{9}{16}$	$3\frac{1}{8}$	$2\frac{5}{8}$	$2\frac{1}{2}$	$\frac{7}{8}$	.260	$\frac{7}{16}$	$\frac{17}{32}$	$\frac{1}{4}$	$\frac{1}{4}$	.06	$2\frac{15}{16}$	.602	.05016	2
3	.778	.938	$3\frac{3}{16}$	$3\frac{7}{8}$	$3\frac{1}{4}$	$3\frac{1}{16}$	$1\frac{1}{16}$	.322	$\frac{9}{16}$	$\frac{23}{32}$	$\frac{5}{16}$	$\frac{9}{32}$	.08	$3\frac{11}{16}$	.602	.05016	3
4	1.020	1.231	$4\frac{1}{16}$	$4\frac{7}{8}$	$4\frac{1}{8}$	$3\frac{7}{8}$	$1\frac{1}{4}$	.478	$\frac{5}{8}$	$\frac{31}{32}$	$\frac{15}{32}$	$\frac{5}{16}$	.10	$4\frac{5}{8}$	.623	.05191	4
5	1.475	1.748	$5\frac{3}{16}$	$6\frac{1}{8}$	$5\frac{1}{4}$	$4\frac{15}{16}$	$1\frac{1}{2}$	.635	$\frac{3}{4}$	$1\frac{13}{32}$	$\frac{5}{8}$	$\frac{3}{8}$	.12	$5\frac{7}{8}$	.630	.05250	5
6	2.116	2.494	$7\frac{1}{4}$	$8\frac{9}{16}$	$7\frac{3}{8}$	7	$1\frac{3}{4}$	.760	$1\frac{1}{8}$	2	$\frac{3}{4}$	$\frac{1}{2}$	.15	$8\frac{1}{4}$	.626	.05216	6
7	2.750	3.270	10	$11\frac{5}{8}$	$10\frac{1}{8}$	$9\frac{1}{2}$	$2\frac{5}{8}$	1.135	$1\frac{3}{8}$	$2\frac{5}{8}$	$1\frac{1}{8}$	$\frac{3}{4}$	.18	$11\frac{1}{4}$	.625	.05208	7

$\frac{5}{8}$ inch per foot. Table I shows the dimensions of Morse taper shanks and sockets. Sometimes a key is inserted in the socket to prevent the drill from turning, and a keyway must then be cut in the drill, as shown at *a*, view (*d*).

37. Short Shanks and Sockets.—The standard sizes of drill shanks and tangs were adopted years ago and were considered strong enough for the requirements of that time; but the tangs have often broken off, as shown at *a*, Fig. 27 (*a*), when the drills were used in modern drilling machines, due to the greater strain resulting from the higher speeds and the harder or tougher materials. A drill with a broken tang may be held and driven by a setscrew that passes through the socket and bears on a flat formed on the taper shank. Another method is to turn down the broken end and to cut a new tang of standard size on it; or, the taper shank may be left just as it is, and a new tang may be cut on it. In the latter case, however, the shank will be short and will require a shorter drill socket. Gauges for short tangs are made for the different sizes of taper shanks. One of these is shown at *b* in view (*b*), in position on the shank of a broken drill. The form of the new tang is marked off by scribing along the gauge, and the metal is then cut away. The new tang thus made is considerably stronger than the old one. Drills are sometimes made with two tangs on the shank, the larger one corresponding to the short form just described and the smaller one being of standard size. If the smaller tang breaks, the drill is then used in a short socket.

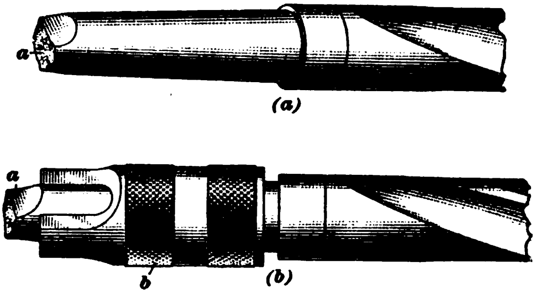
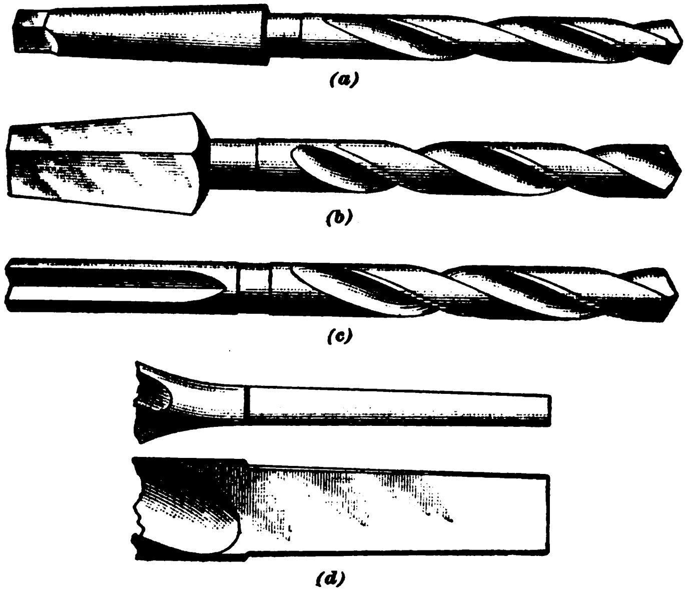


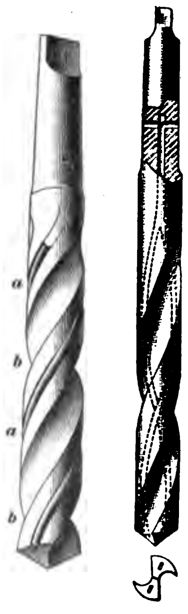
FIG. 27

38. Special Forms of Drill Shanks.—The taper shanks of twist drills are commonly made smaller in diameter than the drills, but special drills are made as shown in Fig. 28 (*a*), with taper shanks one or two sizes larger, to prevent breakage. Drills having square tapered shanks, as shown in (*b*), are used in ratchets; also, the square shank is often formed on flat drills forged in the smith shop, as it is cheap and easily made of any required size. Drills with straight shanks are apt to slip in the chuck, thus wearing both the chuck jaws and the drill shanks. To prevent this, two **V**-shaped grooves are cut in the opposite sides of the shank, as shown in (*c*), and use is made of a special chuck having two jaws that enter the grooves. The flat shank shown in (*d*) is also intended to prevent slipping. It is of standard taper and is used in a special socket. Special forms of drill shanks and methods of driving are required largely where high-speed drills are used, as more power is required to drive such drills at the speed at which they do the best work.


(a)
(b)
(c)
(d)
FIG. 28

LUBRICATION OF DRILLS

39. Application of Lubricants.—In drilling wrought iron and steel, the drill point must be lubricated. The lubricant is usually applied by dropping it into the hole and permitting it to run down along the sides of the hole and the drill. This method has been found rather unsatisfactory, as the cuttings, in working their way to the surface, tend to carry the lubricant up, and in some cases very little, if any, reaches the drill point where it is most needed.



(*a*) (*b*)

FIG. 29

40. In Fig. 29 (*a*) is shown a very simple method by means of which better lubricating conditions are obtained. Two spiral grooves *a* are cut parallel with the flutes *b*, thus forming separate channels for the lubricant. There is some danger that these grooves may become clogged by fine particles that work around the drill, and small brass tubes are brazed into the grooves, as shown, in order to insure an unobstructed flow to the drill point. Another way is to make the drill with holes running through the solid metal, as shown in (*b*). These drills are made from straight-fluted stock in which the oil holes are drilled before the drills are heated and twisted.

41. Provision for Supplying Lubricants.—The lubricants may be carried to the holes in the drill through the socket or through a small attachment at the lower end of the socket. Fig. 30 illustrates an attachment that is frequently used. A collar *a* is fitted to the lower end of the drill socket, as shown, and is kept from turning with the spindle by a pipe that rests against the column of the machine and through which the oil is conveyed to the collar. Inside the collar, and immediately over a pair of holes in the socket that correspond to the upper holes in the drill, a circular groove *b* is turned, thus forming a connection between the outer pipe *c* and the drill. The oil is supplied by an oil pump, under sufficient pressure to insure a steady flow to

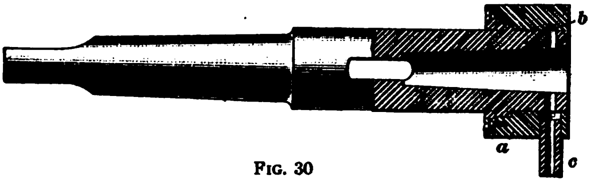
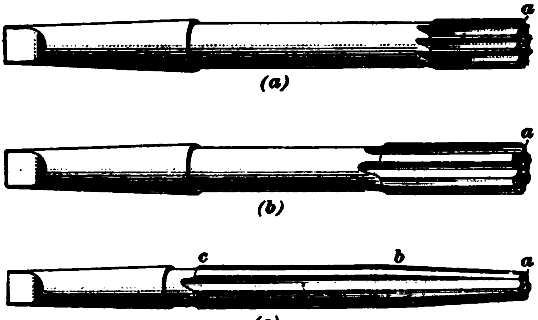


Fig. 30

the drill point, and is carried to the attachment by a flexible tube.

REAMERS

42. Machine Reamers.—The usual type of machine reamer consists of a piece of round steel having a shank formed at one end and a series of lengthwise flutes cut at the other end. If the fluted part is of the same size throughout, the reamer is a straight reamer. Two forms of straight reamers are shown in Fig. 31. That shown in (*a*) is known as a *chucking reamer*. A very slight bevel is formed on the points of the teeth, as shown at *a*, and the cutting edges thus produced remove the stock to a depth of $\frac{1}{64}$ inch or less. The remainder of the fluted part, which is of uniform size, smooths the hole. The *rose chucking reamer*, shown in (*b*), has only about half as many flutes as the ordinary chucking reamer and is beveled considerably more at



(a)

(b)

(c)

Fig. 31

the ends of the teeth, as shown at *a*. The teeth are heavier, and remove considerably more metal than those of the chucking reamer. A reamer for bridge and boiler work is shown in (*c*). The tapered part from *a* to *b* removes the metal and the straight part from *b* to *c* smooths the hole. Machine reamers are often made .003 inch under size, to allow for hand reaming; and if they are made to size, they wear under size by use.

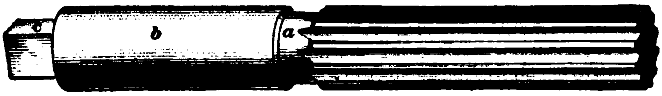


Fig. 32

43. Hand Reamers.—A type of hand reamer is shown in Fig. 32. The fluted part is about twice the length of the fluted part of a machine reamer of the same size. Near the middle, the hand reamer is necked down, as shown at *a*, and the shank *b* is ground accurately to the size of the reamer. The upper end *c* is squared to take a wrench, by which the reamer is turned. For a short distance from the bottom end, the fluted part is tapered about .005 inch so as to enter the hole easily. Some makes of hand reamers have a shallow screw thread cut for a short distance from the lower end, so that they will feed more easily. Hand reamers are used for finishing holes reamed by machine reamers. They remove from .003 to .005 inch of metal, and leave a smooth, true hole.

44. Shell Reamers.—An ordinary shell reamer of the form commonly used in the shop is shown in Fig. 33. A hole *a* having a taper of about $\frac{1}{16}$ inch to the foot extends through it, and across the top are cut two grooves, one of which is shown at *b*. The grooves fit over lugs on the shank by which the reamer is held, and thus enable the shank to drive the reamer without any slip. Shell reamers are cheaper than solid reamers and occupy less storage space in the tool room; also, when they wear out, only the shell needs to be replaced, as the shank is a separate piece.

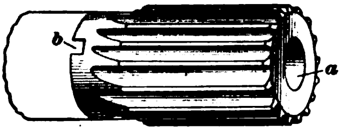
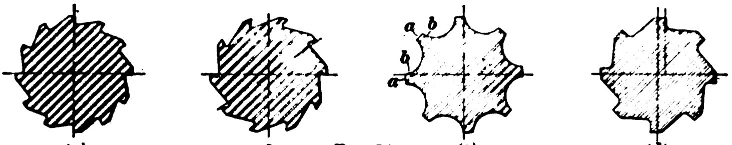


Fig. 33

45. Cutting Faces of Reamers.—The sections of several kinds of reamers shown in Fig. 34 serve to illustrate the forms of the cutting faces. Ordinarily, the front faces of the teeth lie on the center line through the section, as in (*a*). They should never be undercut, as in (*b*), or the reamer will chatter; chattering will cause the teeth to gouge into the metal, and the result will be a damaged or enlarged hole, or possibly a broken reamer. If the reamer is made as shown in (*c*), with curved faces *a* and *b*, there will be no chattering, as the edges will take a scraping cut. The form shown in (*d*) is a special form used for brass. The cutting faces are set forward from the center line but parallel to it, the distance between the two being increased as the size of the reamer increases.

46. Number of Cutting Edges.—A reamer should always have enough cutting edges to guide itself in a straight line through the hole. There should never be less than four, and where the diameter is large enough to make it practicable there should be more. The number of edges should be even and not odd to make it possible to caliper the reamer, unless a ring gauge is used, in which case the number of edges does not matter.



(*a*) (*b*) FIG. 34 (*c*) (*d*)

47. Allowance for Reaming.—In all classes of reaming, the holes should be drilled as nearly to the finished size as possible, so that the reamer need take only a light finishing cut. This preserves the edges, avoids frequent grinding, and lengthens the life of the reamer. An allowance of $\frac{1}{64}$ inch of stock is usually sufficient for reaming in holes having a diameter of 1 inch or less, while in holes having diameters between 1 and 2 inches, $\frac{1}{32}$ inch or less is enough. The general rule to be followed is to ream all holes to standard sizes and to make all fits by varying the sizes of the inner pieces. Twist drills for drilling holes that are to be reamed usually vary by $\frac{1}{64}$ inch in sizes up to 1 inch in diameter. Above 1 inch, they usually vary by $\frac{1}{32}$ inch, and sometimes by $\frac{1}{64}$ inch. If an allowance of $\frac{1}{64}$ or $\frac{1}{32}$ inch is considered too much to be removed by reaming, the drill may be ground so as to cut a hole slightly over its size.

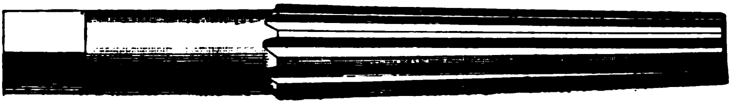


FIG. 35

48. **Solid Taper Reamers.**—Tapered holes for dowel pins and various other purposes have brought taper reamers into very general use. They are fluted and tapered, as shown in Fig. 35, which illustrates a solid taper reamer. The duty of a taper reamer is heavier than that of a straight reamer, as it must remove more metal. The drilled hole is straight and must be a little smaller than the small end of the reamed hole. The amount of metal that must be removed is represented by the part *a c b*, Fig. 36, and depends on the taper required.

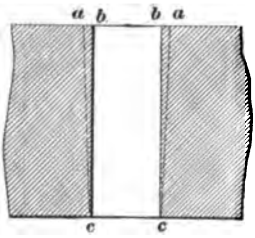


FIG. 36

49. **Roughing Reamers.**—If the taper is great, a roughing reamer, Fig. 37, is first used to remove the excess of metal. This is followed by a finishing reamer, Fig. 35, which should take only a very light finishing cut. In some shops, it is customary to relieve the reamer in heavy work by counterboring steps, as shown in Fig. 38, with drills of increasing sizes. This method, however, takes much time, and it is better to use a stepped reamer, with which the metal can be removed more easily and rapidly than with drills.

FIG. 37

50. Stepped Reamers.—A form of stepped reamer is shown in Fig. 39. The small end *a* is made the size of the drilled hole, and the edges *b*, *c*, *d*, and *e* of the lower ends of the steps form the cutting edges. The diameters are made from .002 to .003 inch less at the top of each step than at the bottom, to provide for clearance and to insure the free operation of the tool. There is also clearance on the bottom as shown at *f g*. This reamer should be followed by the notched roughing reamer shown in Fig. 37, to remove the steps and to enlarge the hole so that it can be completed with the reamer shown in Fig. 35. In holes of very slight taper, the stepped roughing reamer is not generally used, but even here, when a large number of holes are to be reamed, it may be used to advantage, as it preserves the cutting edges and the accuracy of the notched and finishing reamers. Stepped reamers to be used in ordinary drilling machines are made with taper shanks; but when they are to be employed in other kinds of machines they are made with squared shanks.

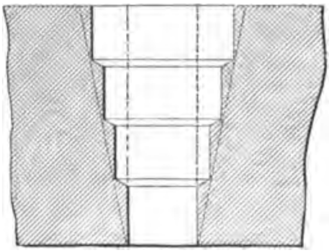


FIG. 38

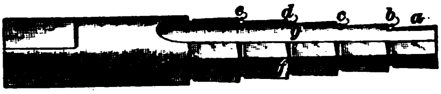


FIG. 39

51. Reamers With Inserted Blades.—The form of reamer illustrated in Fig. 40 has a series of inserted blades, or cutters, which are made of steel and are dovetailed into a solid body. In reamers 5 or 6 inches in diameter, the body is sometimes made of cast iron. The special advantages of this form are its cheapness and the ease with which a damaged blade may be renewed. In the solid reamer, a cracked or broken

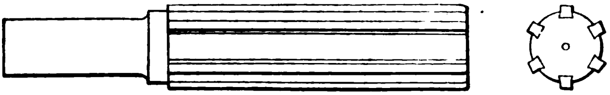


FIG. 40

cutting edge, or any slight warping may throw the whole reamer out of use; but in the inserted-blade type, the damaged cutter is simply driven out of the dovetail, a new one is inserted, and the reamer is as good as new. This is especially advantageous in the larger sizes, which are very expensive. Inserted blades are, however, not practicable in the smaller sizes, as there is not stock enough to support the blades properly. Opinion as to the smallest size in which they can safely be used varies; ordinarily, they are not used in reamers less than 1¼ inches in diameter.

52. Adjustable Reamers.—When a solid reamer is used, the diameter is generally made as much larger than the desired diameter as the limit of error in the working fit will allow, and it is used until the wear has reduced the diameter to the inside limit of error, after which it must be worked over or thrown away. For the best grades of machine work, where the allowable variation is very small, the life of a solid reamer is very short; hence, to provide a way of making allowance for wear, the adjustable reamer was produced. One type of adjustable reamer is shown in Fig. 41. It is adjusted to the desired size by means of a ground tapered plug that acts on the blades *a* and moves them outwards, thus causing the reamer to cut a larger hole. This plug may be locked by the locknut *b* when the adjustment has been made. With this type, a limited amount of wear or the reduction of diameter due to grinding can readily be taken up.

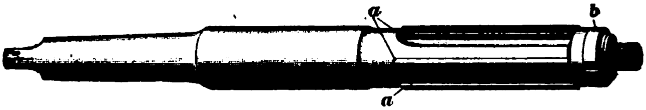
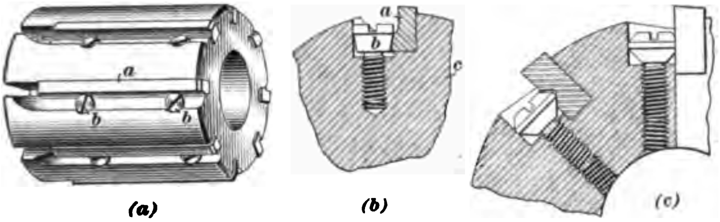


FIG. 41

53. A reamer that is adjustable to allow for wear and also for different sizes of holes, within narrow limits, is shown in Fig. 42 (*a*). The blades *a* are L-shaped in section and rest in slots milled in the body of the reamer. Each is held in place by two or more setscrews *b*. A partial cross-section of the reamer, showing this method of holding the blades, is given in (*b*). The setscrew *b* has a beveled head that bears against a beveled face on the blade *a* and forces the latter firmly against the bottom and side of the slot in the body *c*. Another form of blade is shown in (*c*), but the method of holding it is much like that just described. Thin liners of tin-foil, hard paper, sheet steel, or brass may be placed under the blades in the slots so as to adjust the blades to cut the desired size of hole. Such liners should be free from dents or wrinkles.



(a) (b) (c)

Fig. 42

54. Expansion Reamer.—Another form of adjustable reamer, known as the expansion reamer, is shown in Fig. 43. The reamer is drilled for a taper plug in the lower end, and the sides are slotted, as shown. The plug is threaded, and, when screwed into the end of the reamer, expands it. Reamers of this kind are made as small as $\frac{1}{4}$ inch in diameter, whereas the reamer illustrated in Fig. 41 is not made smaller than $\frac{3}{4}$ inch. The adjustment also is very easily made, and, by taking a number of cuts, a large quantity of metal may be removed. The hole is not at all accurate, however. The expanding plug enlarges the middle of the reamer most, and the cutting edges taper toward the ends, resulting in curved cutting edges without a straight part to guide them. Any unevenness in the structure of the metal as well as the act of reaming causes the reamer to run out of its true course. Where accuracy is essential, this kind of reamer should never be used for the finishing cut.

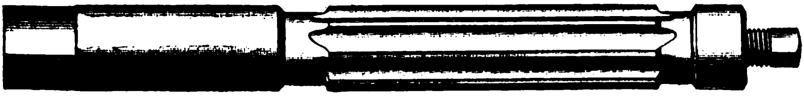


Fig. 43

55. Care of Reamers.—The most serious difficulty met with in reaming is the maintenance of the full diameter of the cutting edges, and in order to keep them in good condition as long as possible, the greatest care should be taken in their use. This is especially necessary with finishing reamers, which may be rendered useless by a very little wear or a slight injury. Reamers should never be pounded or jerked sidewise when in a hole, and when not in use, they should always be kept on wooden shelves or on some other wooden support.

COUNTERSINKS

56. Drill Used as Countersink.—The tools used in countersinking resemble the various forms of drills. In some shops and for some classes of work, the point of a drill is simply ground to the desired taper. When the cutting edges are properly formed, the metal uniform, and the surface square with the hole, fairly good results are obtained; but for general use it is better to have a countersink that is guided by a center guide.

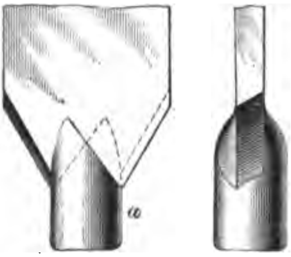


FIG. 44

57. Guide Countersink.—A flat countersink provided with a guide *a*, which fits the hole and holds the tool perfectly central under all conditions, is illustrated in Fig. 44. When used for flat-headed screws, this style of tool is usually made with an included angle of 72° and four cutting edges, as illustrated in Fig. 45.

58. Guide and Collar Countersink.—When a countersink of the same taper is occasionally required in holes of different diameters, a tool like that shown in Fig. 46 is found very serviceable. The guide *a*, instead of fitting the hole, becomes the bearing of a set of collars of different outside diameters, made to fit the different holes in which the tool is to be used. One of these collars is shown in place at *c*, where it is secured by a screw *b* and washer *d*. The cutting edges may be made of any type desired, but four edges, as shown in the illustration, are perhaps the most desirable. There are enough cutting edges to guide the tool properly, and the construction is very simple. Turning the cutting edges back, as shown, forms a bearing for the top of the collar and makes the grinding easier. In some cases, collars are simply slipped over the guide of an ordinary countersink.

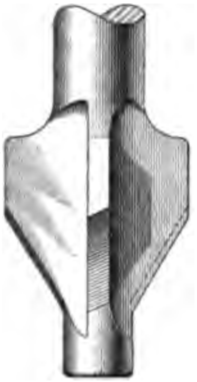


FIG. 45

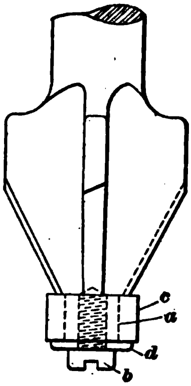


FIG. 46

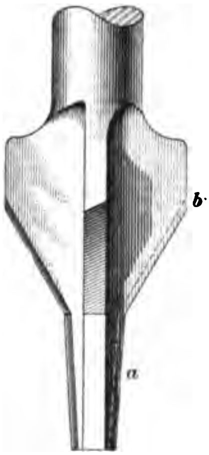
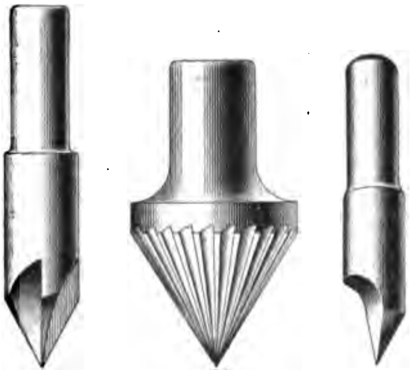


FIG. 47



(a) (b) (c)

FIG. 48

59. Combined Reamer and Countersink.—In plate work, reaming and countersinking may be done at the same time with the combination tool shown in Fig. 47. The lower end *a* is made like an ordinary fluted reamer and does the work of a reamer, and the countersink *b* is formed with four cutting edges ground to the desired angle.

60. Center Countersinks.—Fluted and half-round countersinks, as shown in Fig. 48 (*a*), (*b*), and (*c*), are used almost entirely in reaming centers in lathe work, but these styles may also be used for ordinary countersinking.

COUNTERBORES

61. Small Counterbore.—Small counterbores are made very much like the guide countersink just described, except that the cutting edges are set at right angles to the center line. A counterbore of this kind is shown in Fig. 49.

62. Double-Ended Cutter.—The counterbore shown in Fig. 50 is for large and special holes. It is made from a round bar of steel and has a taper shank. A rectangular hole is cut through it, in which a flat cutter *a* is inserted and held by a key *b*. The end of the bar is made to fit the hole without any play, while the length of the cutter represents the diameter of the counterbore. This cutter cuts on both ends, and great care must be taken to have it project the same distance on each side, and to have the cutting edges ground so that both sides will take equal depths of cut.

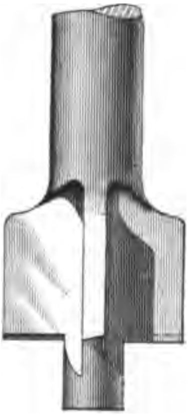


FIG. 49

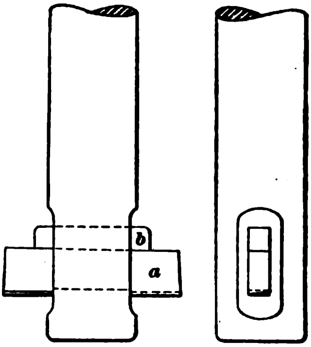


FIG. 50

63. Counterbore for Light Work.—A useful tool for counterboring is illustrated in Fig. 51. A hole *a* is drilled in the bar *b*, in which a round piece of tool steel *c* is inserted and held in place by a pin *d*. The bar is then put in a lathe and the ends of the tool *c* are turned to the desired diameter. The ends are backed off and the cutting edges ground, as shown, flat on face and bottom. The lower end of the bar is turned to the diameter of the hole below the counterbore, to form a guide for the tool. This tool gives very good results when operated with care and on light cuts, but the cutter is not heavy enough to stand a very heavy strain.

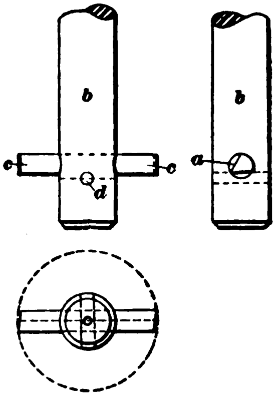
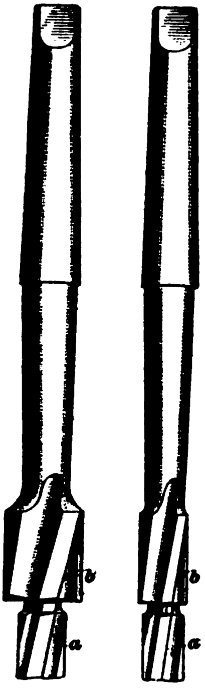


Fig. 51

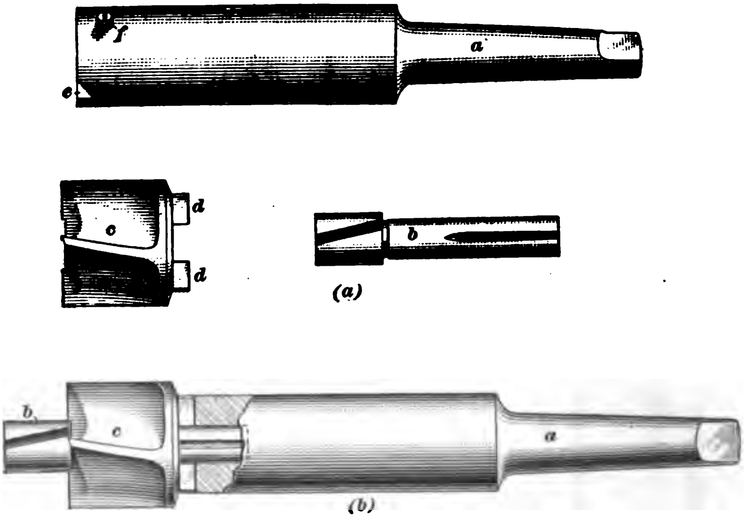


(a) (b)

Fig. 52

64. Standard Counterbore.—Frequently, holes must be counterbored in two operations. For the fillister-head screw, for instance, one counterbore must be used for the head, and another for the body of the screw. In this case the counterbores are made in pairs and are of correct dimensions for standard screws. Such a pair is shown in Fig. 52, (*a*) being the counterbore for the head. The guide *a* is shaped to fit the hole made by the tap drill, and the counterbore *b* is constructed to cut the size of the screw head. The counterbore shown in (*b*) is used to counterbore for the body. Here, again, the guide *a* is made to fit the tap-drill hole, and the counterbore *b* has a diameter equal to that of the screw body. On the counterbores are spiral flutes making an angle of 15° or 20° with the axis. The guides, too, have flutes to make the sharpening easier and to allow the chips to fall out. If the body is counterbored first, it is necessary to use a third counterbore having a guide the size of the screw body.

65. Interchangeable Counterbores.—Counterbores are made in which guides and cutters of different sizes may be used with a standard holder. Such a form is shown in Fig. 53, in which (*a*) represents the several parts of the tool and (*b*) the assembled tool. The same letters are used to mark corresponding parts in both views. The shank *a* is tapered to fit the drill-press spindle and the lower end is bored out to take the guide pin *b*, which passes through the cutter *c*. The cutter has two tongues or lugs *d* that fit in a corresponding slot *e* across the bottom of the holder, and the cutter is thus driven. The guide pin is held in the holder by the setscrew *f*, and holds the cutter in place.



(a)

(b)

FIG. 53

66. Undercutting.—Different methods are used to undercut the bottoms of holes so as to reduce the work of tapping. This operation is also sometimes called *bottom counterboring*. One form of tool for this purpose, known as the *Cleveland* *under-cutting tool*, is shown in Fig. 54. The shank *a* must be smaller in diameter than the hole *b* to be undercut; and the difference in diameters must be twice the height of the thread on the tap that is to follow the undercutting tool. A cutter *c* is formed on one side, at the lower end, and the end *d* is made conical to fit the bottom of the drilled hole. The tool is sprung to one side while the cutter is moved to the bottom of the hole. The machine is then started, and as the conical end *d* is pressed down into the conical bottom of the drilled hole by the down feed, the cutter is forced sidewise and the hole is undercut, as at *e*.

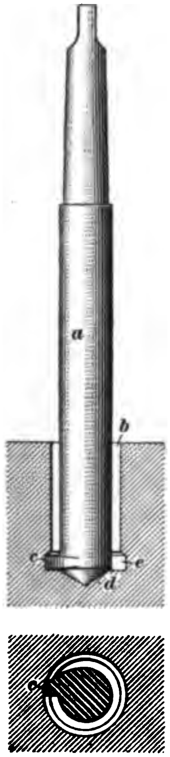
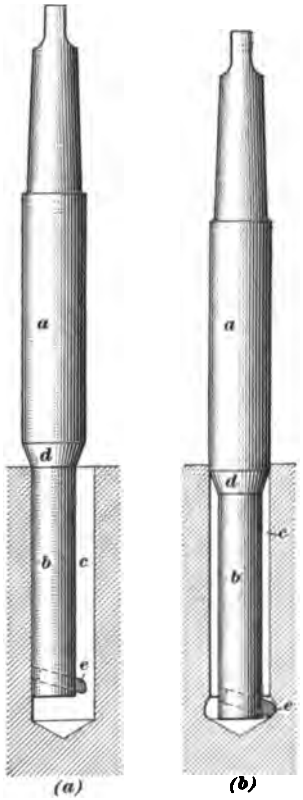


FIG. 54



(a) (b)

FIG. 55

67. The undercutting tool ordinarily used in the shop is commonly made by turning a piece of steel to the shape shown in Fig. 55 (*a*), so that the upper end *a* has a diameter equal to that at the bottom of the thread of the tap to be used. The lower end *b* is made smaller than the drilled hole *c* by an amount equal to twice the height of the thread. The two parts *a* and *b* are joined by a short tapered part *d*, and a cutter *e* is driven into a hole drilled at an angle near the bottom end. The tool is inserted as shown, with the part *b* in contact with one side of the hole. As it is fed down, the tapered part *d* comes against the edge of the hole and gradually forces the cutter *e* over against the opposite side, causing it to undercut the hole. By the time the part *a* has entered the end of the hole, the bottom of the hole has been undercut as shown in (*b*).

SPOT-FACING OPERATIONS

68. Forms of Cutters.—The cutters used for spot facing are the same as those used for counterboring; the only difference in the operation lies in the depth of the cut. A counterbore may be of any depth, but spot facing is carried just deep enough to form a smooth bearing surface. The bar with an inserted cutter is especially well adapted to spot facing flanges of cylinders, cast-iron pipe flanges, etc.

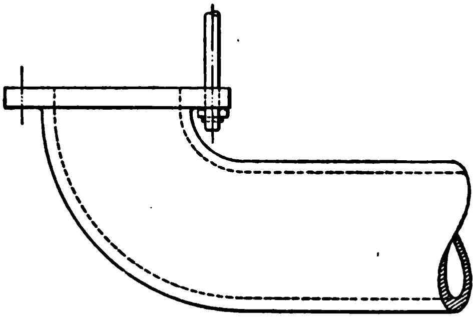
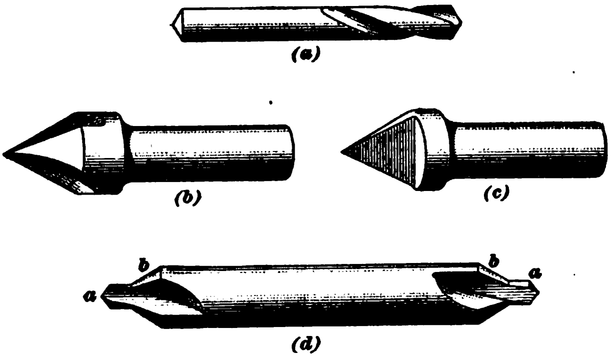


FIG. 56

69. Spot Facing the Under Side of a Flange.—A case in which an ordinary bar and cutter cannot be used for spot facing is shown in Fig. 56, in which the under face of the flange just above the inside bend must be spot-faced. The flange is drilled in the ordinary way, after which the drill is removed from the socket and the cutter bar is put in its place. The cutter is then removed from the bar, the bar is passed through the hole, and a left-hand cutter is put in, with its cutting edges toward the flange. The spot facing is then done by feeding the drill spindle upwards, after securing the bar firmly in the spindle. This operation is slow, and should be used only when facing cannot be done in the usual way.

CENTER DRILLS AND TAPS

70. Center Drills.—The drills used for drilling center holes in the ends of pieces of work are short twist drills of small diameters, of the form shown in Fig. 57 (*a*). They are made short because they are used to drill only shallow holes, and also because shortness lessens the danger of breakage. Center reamers of the forms shown in (*b*) and (*c*) are then used to ream the drilled holes to the proper angle. The center hole may be formed in one operation by the use of a combination center drill and countersink like that shown in (*d*), which consists of a small twist drill *a* at the point and a countersink *b* just behind it. The tool is made double-ended as a matter of economy in the use of stock.



(*a*)

(*b*)

(*c*)

(*d*)

FIG. 57

71. Taps.—The forms of taps used in drilling machines resemble hand taps. If the holes to be tapped do not run clear through the work, a *taper tap* must be used to start the thread and a *plug tap* to complete it to a point near the bottom. When a full thread must be cut all the way to the bottom of a hole, the plug tap is followed by a *bottoming tap*. These three forms of taps are shown in Fig. 58. In the case of holes that pass through the material, the taper tap alone may be used. In high-speed machines, such as pneumatic drills, a long taper tap gives the best results, as less material is removed by each tooth, the work being distributed along the length of the tap. Most machine tapping, however, is done by using the plug tap only. The shanks of taps that are to be employed in the drilling machine only may be made to fit the spindle of the machine for which they are intended. When they are required for general use, special sockets are needed to receive the square shanks of the taps.

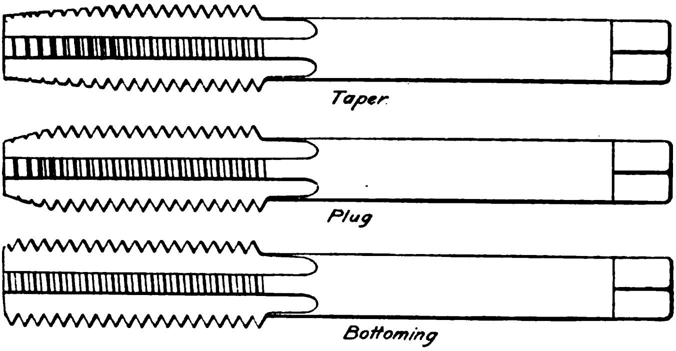


FIG. 58

HOLDING DEVICES FOR DRILLS

72. Straight Socket With Setscrew.—Various devices for holding tools in drilling-machine spindles have been brought into use. One of the earliest of these, which is still found in some shops, consists of a straight hole in the bottom of the spindle, with a setscrew to hold the drill, as shown in Fig. 59. The disadvantage of this form, however, is that a burr is formed on the drill by the pressure of the setscrew. This burr roughens the inside of the socket and makes the removal of the drill difficult. When the shank does not fill the socket completely, the pressure of the setscrew on one side throws the drill off center in the spindle and results in the cramping of the drill and a poorly formed hole, and often in a damaged or broken drill. Also, the head of the setscrew is liable to injure the workman.

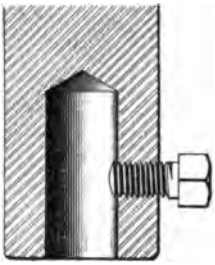


Fig. 59

73. Socket for Taper Shank.—A very simple and efficient means of holding a drill having a taper shank is shown in Fig. 60. The drill spindle *a* is made with a tapered hole *b* at the lower end. At the upper end, the hole is made flat on two sides to receive the tang, or flattened projection, on the upper end of the drill shank. The taper is just great enough to hold the drill when put in place with a quick motion of the hand or under slight pressure. The drill shank must, of course, be made with precisely the same taper as that in the spindle, so that both of the tapered surfaces will be in contact at all points. The drill is prevented from slipping in the spindle by the friction between the tapered surfaces and also by the tang; hence, the tang should fit fairly well. The drill is removed by driving a taper key *c* into the slot *d* in the spindle. The slot is so located that the point of the key just passes over the end of the tang, but when the body of the key is driven in, the drill is forced out.

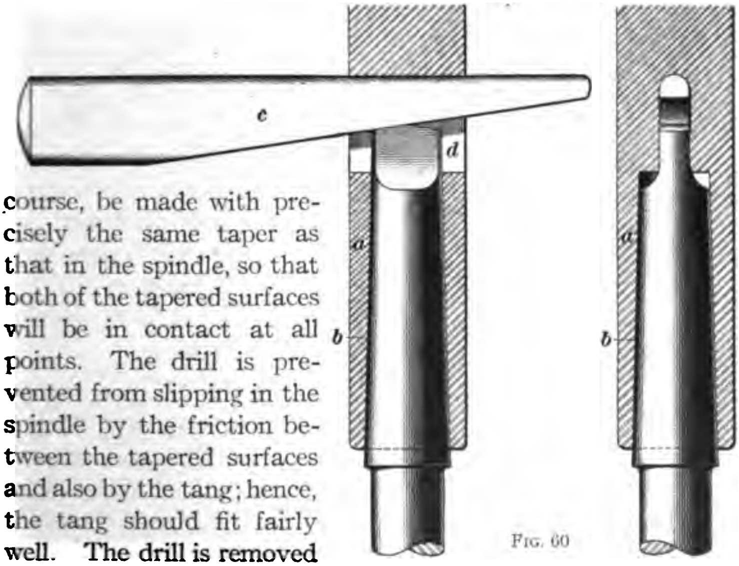


Fig. 60

74. Drill Sockets, or Collets.—All sizes of drills cannot be made with the same size of shank; consequently, it is necessary to have a number of drill sockets or collets, Fig. 61 (*a*) and (*b*), to take the sizes of drills that do not fit the spindle. The upper end of the socket is made to fit the spindle, or the next larger size of socket, and the lower end is made to fit the desired drill. Collets are also found very serviceable where it is desirable to use a drill with one kind of shank in a spindle intended for another. A collet for a taper-shank drill and a straight spindle is shown in (*c*).

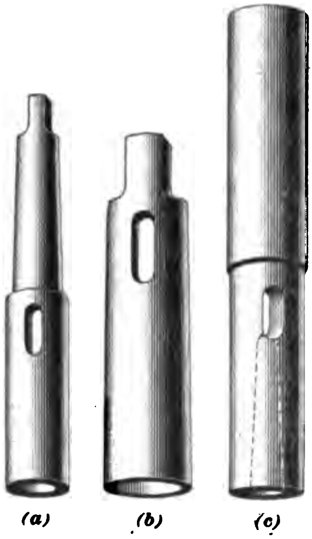


FIG. 61

75. Pin-Grip Socket.—A form of drill socket that allows the drill to be changed while the spindle is running is shown in Fig. 62. The shank of the socket *a* is made to fit the taper of the spindle *b*, and a collet *c* is made to fit over the shank of the drill *d*. The body of the socket *e* is bored out straight to receive the collet, which is held in place by two pins that enter the groove *f* and are controlled by the collar *g*. To remove the collet, the collar *g* is raised with one hand, while the drill is in motion, and the collet is removed with the other hand.

76. A partial section of the pin-grip socket is shown in Fig. 63. The collar *g* is bored out to form an internal cam. When the collar is in its lowest position, it holds the pins *h* in, as shown, their points entering the groove *f* in the collet. When the collar is raised to the position *i* indicated by the dotted lines, the rapid turning of the socket throws the pins out, thus releasing the collet. The ends of the pins are tapered, so that the weight of the collet or drill will assist in moving them out when the machine is running at a slow speed. The collar is brought back by its own weight when released by the hand. The collet *c* is made with a tang *j*, which stands between the two pins *k*, thus causing it to rotate with the spindle.

77. Key-Grip Socket.—In very heavy work, the tang of the drill sometimes is twisted. Fig. 64 illustrates a device that grips the body of the shank as well as the end. The illustration shows the grip socket with a part cut away, thus exposing all the working parts. The shank and tang are of the ordinary taper type. A keyway *a* is cut in the shank of the drill with a circular cutter, thus making the bottom the arc of a circle. The key *b*, which fits the bottom of the keyway and also a slot in the socket, is held in place by a collar *c* that is bored eccentrically. When in the position shown, this collar causes the key to grip the shank and keeps it from working out, as well as prevents it from turning in the socket. To remove the drill, the collar is turned to a position where the key is free to move out

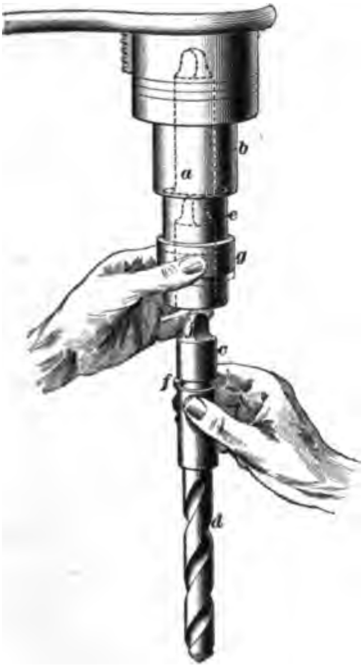


FIG. 62

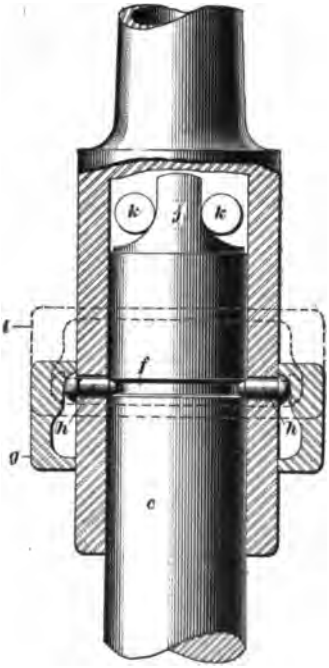


FIG. 63

of the drill shank, and the drill is driven out in the usual way. This device can be used with any of the standard taper-shank drills by simply cutting the keyway.

A number of other designs of drill sockets are made; these include some form of key or driving device at the lower end of the opening. This key enters a corresponding groove in the drill shank. There are also many special forms of high-speed drills and special methods of driving them.

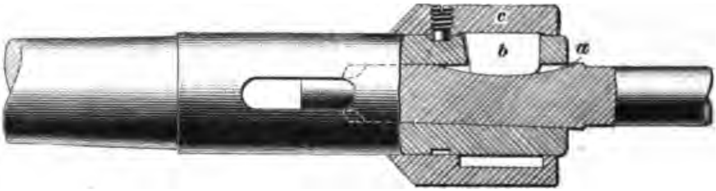


Fig. 64

78. Chuck for Small Drills.—Drill chucks that grip the drill shank at three or more points are used for the smaller drills. Fig. 65 (*a*) shows a type that is largely used. The body of the chuck *a* is held in the drill spindle by means of a taper shank. In three holes *b* converging toward the center line, as shown, are three jaws *d*, which, when forced forwards by the nut *c*, close in on the drill shank and grip it firmly. The jaws are so formed that the parts that grip the drill are always parallel and therefore grip various sizes equally well.

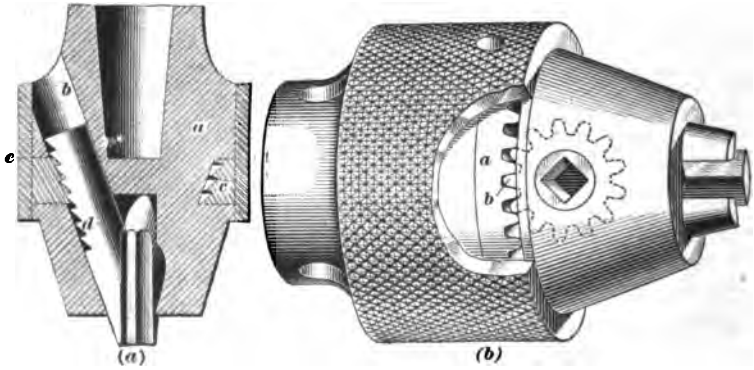
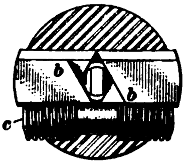


Fig. 65

79. The nut on the chuck in Fig. 65 (*a*) is held in and turned with the collar *e*, which is nurled on the outside to furnish a better grip for the hand. It is in two parts that are held in place in the chuck body by the collar, which is bored to a slight taper and driven over the nut. It is however, an easy running fit on the body. The chuck is taken apart by carefully driving off the tapered collar. One or more holes are drilled in the collar, so that a spanner can be used to tighten the chuck. A tighter grip on the drill can be obtained by the method shown in (*b*). Gear teeth are cut on the lower side of the nut *a*, and in mesh with these is the pinion *b*, which may be turned with a square-ended key or wrench.



80. Chuck for Heavy Drills.—A form of chuck that is used for heavier drills than the one just described is shown in Fig. 66. Across the lower end of the body of the chuck is cut a slot *a* in which two jaws *b* are free to move toward and away from the center. The jaws are controlled by means of a screw *c*, one end of which has a right-hand thread that engages with the thread on one jaw, and the other end a left-hand thread that engages with the other jaw. The jaws are so guided that the faces are always parallel, and drills of any diameter that will enter the chuck are gripped equally well. A hole in the plate *e*, which is screwed to the bottom of the body, is large enough to take only the largest diameter of drill for which the chuck is designed. A plate *f* just above the jaws contains a slot *g* made to fit the tang on the upper end of the drill shank, thus preventing the drill from slipping in the chuck.

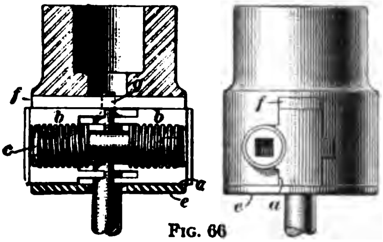


FIG. 66

81. Quick-Acting Roller Chuck.—A side view and a bottom view of a quick-acting automatic chuck are shown in

Fig. 67 (*a*) and (*b*). The drill *a* is held in the center of the chuck by three rollers *b*, each of which bears against a curved surface *c* formed on the inside face of the sleeve *d*. The curved surfaces are slanted, so that when the sleeve is twisted in one direction, they force the rollers inwards and grip the drill, and when it is twisted in the other direction, they release the drill. Drills may be changed in this chuck without stopping the drill press. The sleeve *d* is grasped firmly and held from turning; then the drill is removed, and another is inserted, after which the sleeve is released. A coiled spring inside the sleeve immediately acts on the sleeve and turns it so as to cause the rollers to grip the drill hard enough to hold it. When the drill begins to cut, the twisting tends to turn the sleeve still more, and grips the drill still more firmly.

82. Safety Drilling and Tapping Device.—A very efficient safety device for drilling and tapping is illustrated in Fig. 68. A shank *a*, which is tapered to fit the spindle with which it is to be used, has on its lower end an enlarged part that is threaded on the outside and bored out to form a friction seat for a socket *b*. A cap *c*, which has an internal thread to fit the external thread on the shank, clamps the socket between itself and the shank, forming another friction surface between the socket and the cap. Two fiber washers *d* and *e* are placed between the socket and the adjoining surfaces. The cap *c* is tightened on the washers until the friction obtained is sufficient to drive the drill or the tap, and is held in adjustment by the check-nut *h*.

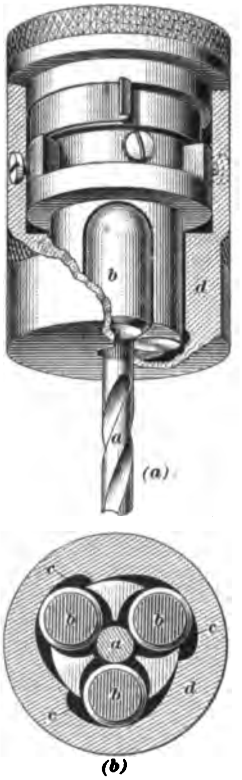


Fig. 67

83. Two spanner wrenches are required to make the adjustment of the device shown in Fig. 68. Drill and tap sockets that fit the required drills or taps are made to fit the socket *b* and are kept from dropping out by the catch pin *l*, which enters the grooves *m* and *n* in the drill and tap sockets and is held in place by a spring and a retaining screw. The sockets are driven by means of two feathers. The tap shank is made about .01 inch smaller in diameter than the tap socket *f*, thus allowing the tap to take its own feed without injury to the thread, and to center itself with the hole without binding. A catch pin *o*, held in place by a flat spring, engages with a groove in the tap and keeps it from dropping out until a force greater than its own weight is applied. A specimen of the taps used, marked *i*, shows how the shank is constructed, *p* being the groove for the catch pin. The drill socket *g*, which is made in various sizes to take drills of different sizes, has a standard taper and a slot *j* at the upper end to receive the tang.

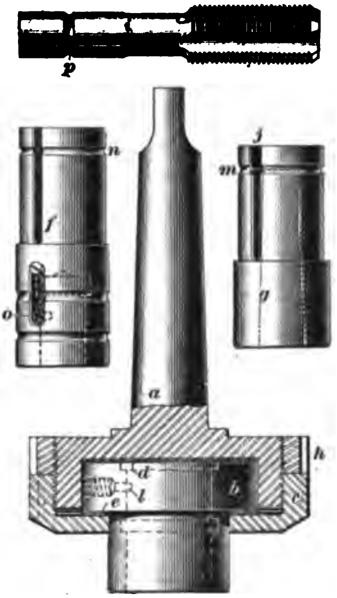


FIG. 68

84. Automatic-Reverse Tapping Chucks.—If a large amount of tapping is done, much time may be saved by the use of a device that will reverse the tap and back it out, either when the tap bottoms or sticks, or when it has run to the required depth. Several such devices are on the market and many of them give very good results. In one class, the mechanism is so designed that the tap travels with the spindle while running forwards, but as soon as it meets with more than a certain amount of resistance, a reversing gear, or set of gears, is thrown into action and the tap is backed out at an increased speed. In another class, the tap is also reversed and backed out when it has run to a stated depth. Such a device, it will be seen, insures safety and saves time.

HOLDING WORK FOR DRILLING

85. Drilling-Machine Table.—The table of the ordinary drill press should furnish a perfectly plane surface standing at right angles to the center line of the spindle. It should also be provided with holes through which bolts may be passed or with radial slots for T-headed bolts, so that work may be clamped rigidly on it. Securing the work properly on the table of a drilling machine is one of the important parts of drilling. A piece that is not properly set or not well secured will not be well drilled, although all other conditions may be perfect.

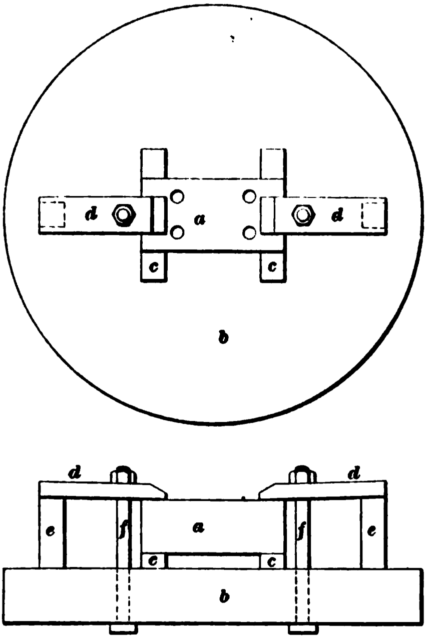


Fig. 69

86. Securing Work.—A plain piece of work, in which the holes are to be drilled at right angles to the face on which the piece rests, may be secured as shown in Fig. 69. The piece *a* to be drilled is laid on the table *b*, with two parallel pieces of iron *c* under it to raise it far enough from the table to prevent damage to the latter when the drill emerges from the piece. Two clamps *d* are then placed with one end of each on the piece over the parallels, and the other ends on blocks or screw jacks *e* of the same height as the top of the piece. Bolts *f* are then put through the clamps and the table, as near to the work as the holes will allow, and the nuts are screwed down until the clamps press firmly on the piece and hold it rigidly enough to prevent any slipping while the drill is passing through it.

87. The essential features of clamping are shown in Fig. 69. A piece must always be set so that the center line of the hole to be drilled is parallel to the center line of the spindle, and must be clamped rigidly in that position. Great care must be taken to have all the supports so adjusted that the piece will not spring out of shape when the clamps are tightened down. Irregular parts that have no flat surfaces on which to rest must be supported with jacks or blocks at different points. When pieces that are too large to be supported entirely on the table are to be drilled, the overhanging parts must be blocked up, to prevent any undue strain on the table or any spring in the piece itself.

88. Plain Clamp.—The clamps are often made by drilling a hole a little larger than the bolt in a piece of flat iron of suitable length. This kind of clamp is sometimes made with an offset, as shown in Fig. 70 (*a*), which serves the purpose of lowering the clamp-bolt nut so that it does not interfere with other parts, and allowing shorter bolts to be used.

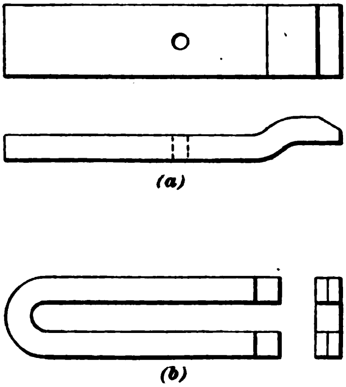


FIG. 70

89. U Clamp.—A more convenient clamp is made of a piece of square iron bent to the form of a **U**, as shown in Fig. 70 (*b*), the inside width being just great enough to take the bolt freely. Such a clamp can be removed and replaced without taking the nut off the bolt. In some cases, the other form is of advantage, however, and both are found among the accessories of a drilling machine. The **U** clamp is often made without the offset at the end, shown in the illustration.

90. Screw Jack.—The screw jack consists of a cast-iron foot *a*, Fig. 71, which has a tapped hole running vertically through it and a square-headed bolt *b*, with a thread cut the entire length of the body, screwed into it. The top of the bolthead should be faced to form a good bearing surface, and the corners rounded to prevent any digging when adjusting the height. The bottom of the foot is sometimes left rough, but it is better to have it finished.

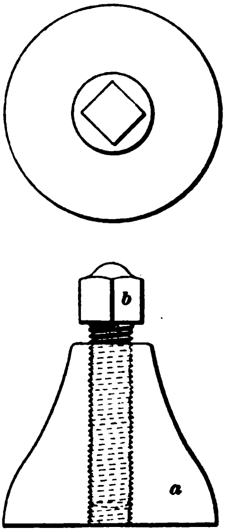


FIG. 71

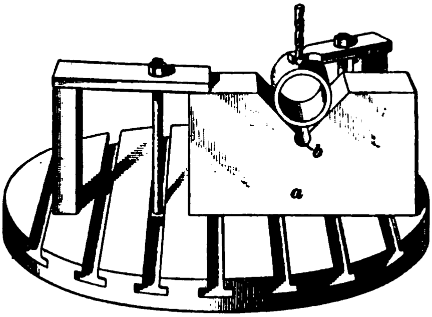


FIG. 72

91. Parallels.—The parallels used in blocking up the work should be carefully planed and should be made of rectangular cross-section and in pairs. Sometimes parallels are made with the width exactly twice the thickness. It is convenient to have the width of each pair equal to the thickness of the next larger pair.

92. V Blocks.—Cylindrical parts are usually supported on V blocks, as shown at *a*, Fig. 72. The V blocks should be made in pairs, so that a piece resting on them may be exactly parallel to the drill table. It is usually of advantage to make the block wide enough to support short pieces with a single clamp, as shown. A hole *b* drilled at the point of the V will form a

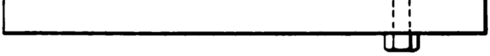


FIG. 73

clearance in planing. The two sides of the **V** usually make an angle of 90° with each other.

93. Angle Plates.—A piece with a flat surface at right angles to the surface to be drilled is usually attached to an angle plate by means of clamps, as shown in Fig. 73. If the overhanging part is too long, it should be blocked or jacked up and clamped at another point as far away from the angle plate as possible. The angle plate must, of course, be firmly bolted to the table. Angular pieces are frequently supported on angle plates of the same inclination as the pieces. For instance, the piece *a* in Fig. 74 is clamped to an angle plate *b* of the same inclination, thus bringing the surface to be drilled parallel to the table.

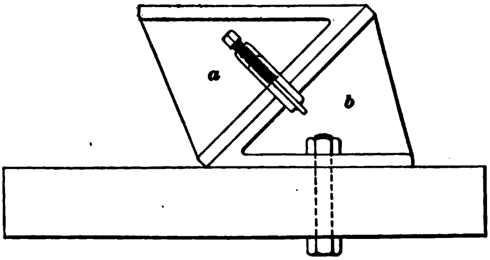


FIG. 74

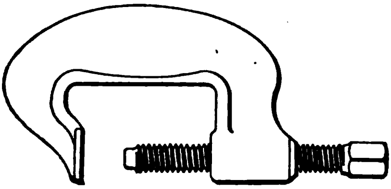


FIG. 75

94. C Clamp.—The style of clamp shown in Fig. 73 is known as a **C** clamp and is shown on a larger scale in Fig. 75.

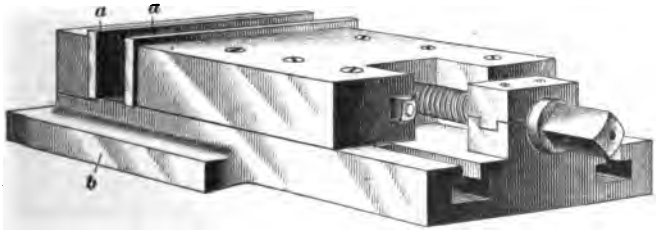


FIG. 76

95. Vise.—A vise as shown in Fig. 76 is often used for supporting the work. It is especially convenient where the bottom of a piece is irregular and yet has parallel sides that the vise may grip between the jaws *a*. A lug *b* on each side forms a convenient means of clamping the vise to the table.

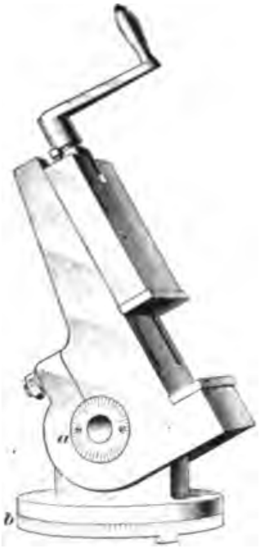


Fig. 77

96. Universal Vise.—A universal vise that may be bolted to the table of a drilling machine and may be rotated both in a horizontal and in a vertical direction is shown in Fig. 77. The two circles *a* and *b* are graduated, as shown. Such a vise is especially useful where holes must be drilled at different angles in the same piece. The piece can be set either horizontally or vertically, and, by having the circles graduated, it can be rotated to any desired angle without resetting.

97. Drilling Parts Together. When two adjoining pieces are to be drilled so that the holes in the two are to match perfectly, they should be drilled together whenever practicable. This insures a perfectly continuous hole, and avoids a great deal of awkward and expensive fitting.

DRILLING

(PART 2)

DRILLING MACHINES

CONSTRUCTION AND OPERATION

DRILLS FOR MEDIUM WORK

1. Kinds of Drilling Machines.—The drilling machines most commonly used in the machine shop are classed as drill presses, radial drills, column or post drills, horizontal drills, traveling-head drills, gang or multiple-spindle drills, sensitive drills, and portable drills. There are also a number of kinds of special drills. Drilling machines used for ordinary work are usually made so that the work is held stationary during the drilling operation while the tool is rotated as it is fed into the work. Sometimes, however, the work is rotated and the tool is fed down into it without turning.

2. Heavy Drill-Press.—A form of drill press that is used on a large variety of work is shown in Fig. 1. As the column *a* forms the main part of the machine, it must be stiff enough to prevent springing during drilling. It is held upright by a heavy floor plate *b* that is used also as a support for large work. An arm *c* is carefully fitted on the lower part of the column and carries a table *d* on which small work is held for drilling. The arm may be swung around the column; also, it may be moved up or down by turning the handle *e*, which drives

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a small pinion that meshes with the rack *f*. The rack is free to slide around the column as the arm is swung, but it is prevented from moving up or down by the shoulders between which it fits. The table can be turned on the pin by which it is held in the end of the arm. Both the table and the arm may be locked in position by tightening the clamping screws.

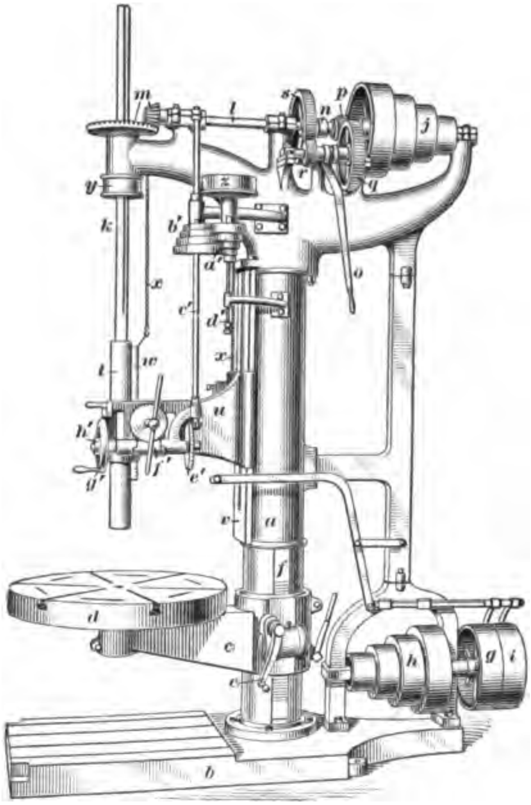


FIG. 1

3. Driving of Drill Press.—The drill press shown in Fig. 1 is driven from a countershaft or a line shaft by a belt that runs on the pulley *g*, which is fastened to the same shaft as the cone pulley *h*. This belt is shifted to the loose pulley *i* when the drill is to be stopped. From the cone *h* a belt runs to the similar cone *j* at the top. When the belt is on the largest pulley of the lower cone and the smallest pulley of the upper cone, the drill has its greatest speed; and when the belt is on the smallest pulley of the lower cone and the largest pulley of the upper cone, the drill has its least speed. The upper cone drives the spindle *k* through a short horizontal shaft *l* and the bevel gears *m*.

4. Back Gearing of Drill Press.—The driving shaft *l*, Fig. 1, is made in two parts that may be connected or disconnected by moving the clutch *n* by means of the handle *o*. A small gear *p* is fastened to the driving shaft near the cone pulley and meshes with the large back gear *q*, which thus turns at a slower speed than the gear *p*. The back gear *q* is fixed on a quill, or sleeve, that has a small gear *r* at its other end, and the gear *r* meshes with a gear *s* on the shaft *l*. The back gears *q* and *r* can be shifted along the shaft on which the quill turns, and may thus be thrown out of mesh with the gears *p* and *s*. The handle *o* is so arranged that when the clutch *n* is thrown into action, the back gears are thrown out of mesh; and when the clutch is thrown out of action, the back gears are moved into mesh. When the back gearing is in mesh, the drill spindle is driven slowly but with great force.

5. Drill-Press Spindle and Head.—The lower end of the spindle *k*, Fig. 1, rotates inside the cast-iron sleeve *t*, which passes through a hole bored in the outer end of the head *u*. The head may be moved up or down on the slide *v*, and its purpose is to steady the end of the spindle. The cast-iron sleeve *t* has a rack *w* at one side, by which it may be moved upwards or downwards, carrying the spindle with it, and thus giving the feed to the drill. The upper end of the spindle has a keyway cut in it, to fit a feather set in the hub of the larger of the bevel gears *m*. Thus, the spindle is driven when the bevel gear turns, but may move up and down in the gear when the sleeve *t* is raised and lowered. A tapered hole is bored in the lower end of the spindle to receive the drill shank. The chains *x* attached to the sleeve and to the head pass over pulleys, and run down inside the column *a*, where counterweights are hung. The sleeve and the head are thus counterbalanced and may be raised easily.

6. Feed-Mechanism of Drill Press.—The feed of the drill press shown in Fig. 1 is obtained from the pulley *y*. A belt runs from this pulley to the pulley *z*, which drives a set of gears *a′* that mesh with a corresponding set *b′* on the vertical shaft *c′*. The gears in each set are of different sizes, and by moving the rod *d′*, the pulley *z* can be made to drive the shaft *c′* through any one of the four pairs, thus enabling the shaft *c′* to be turned at different speeds. The shaft *c′* has at its lower end, a bevel pinion that drives a bevel gear *e′* on the worm-shaft *f′*, and the worm on the worm-shaft drives a pinion that meshes with the rack *w*. In this way the downward feed of the spindle may be varied to suit the work. The drill may be fed by hand by turning the hand wheel *g′*. Power feed is obtained when the bevel gear *e′* is clamped to the worm-shaft by tightening the nurled nut *h′*.

HIGH-SPEED DRILLS

7. Carbon Steel and Alloy Steel.—The two kinds of steel used for drills are carbon steel and alloy steel, the latter being also called high-speed steel. Carbon steel suitable for drills contains about 1¼ per cent. of carbon, and drills made from it are hardened by being heated to a cherry red and then dipped endwise into cold water, brine, or a special hardening bath. Alloy, or high-speed, steel contains different percentages of one or more of the substances manganese, chromium, nickel, tungsten, or vanadium. It is not injured by the temperatures to which a cutting tool is heated, and drills made of it are hardened by being heated to a white heat and then cooled by a blast of air. Drills made of alloy steel can be run at from two to three times the speed of carbon-steel drills of the same size.

8. Ball-Bearing Drill Spindle.—The ordinary type of drill spindle is in direct contact with the sleeve in which it turns, and there is considerable friction between the two parts. This friction is greatly increased if the lubrication is poor or if the parts are badly adjusted. Tests on ordinary machines driven by 1¼-inch belts showed that the limit of the capacity of the machines was reached when a $\frac{3}{8}$-inch carbon-steel drill was used; but when ball bearings were used, instead of plain bearings, on the spindle, a $\frac{3}{4}$-inch high-speed drill could be employed. As a result of these tests, a class of light drills with ball bearings has been made for use at high speeds.

RADIAL DRILLS

9. Simple Radial Drill.—A machine that is designed for a class of work that cannot well be mounted upon a drill-press table, either because of its size or weight, is shown in Fig. 2 and is called a radial drill. The spindle is carried in a head that traverses back and forth on a radial arm *a*, which is hinged on a vertical slide *s* on the column *b*. The spindle is driven

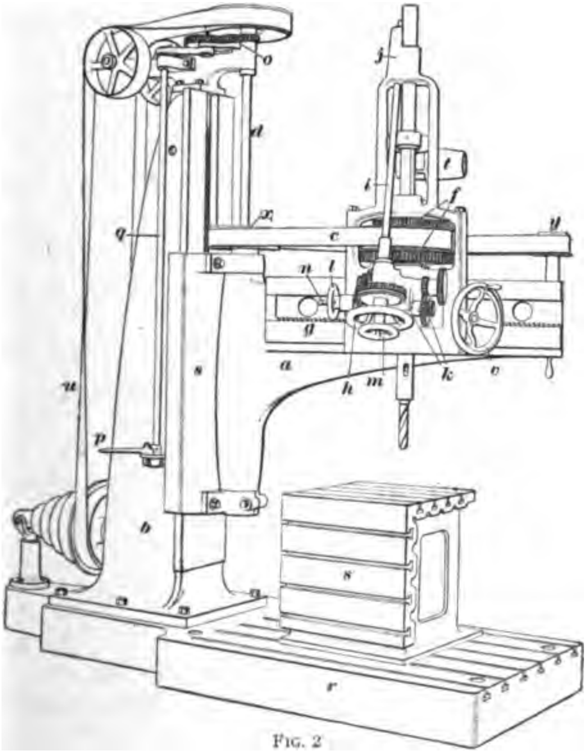


FIG. 2

by a belt *c* that runs over the pulley *x* on the shaft *d* and over the pulley *y* on the end of the arm. An intermediate pulley that travels with the head, and about which the belt is carried by means of an idler, transmits the motion to the spindle. The plan view of the belt *c* is shown in Fig. 3. The driving pulley *x* is splined upon the shaft *d*, and the pulley *y* is supported on the outer end of the arm *a*; *z* represents the driving pulley on the drilling head, and *w* represents the idler. The motion is transmitted either to the spindle direct or through back gears shown at *f*, Fig. 2. A counterweight *t* balances the weight of the spindle, thus relieving the feeding device. The head is traversed by means of a hand wheel *v*, which has a worm on the other end of its shaft engaging with the rack *g*.

10. Both hand feed and power feed are provided on the drill shown in Fig. 2. The former is operated by the hand wheel *h* on the shaft *i*, which has on its end a worm at *j* that engages with a rack on the upper end of the spindle. The power feed is obtained by means of a worm on the spindle running in a worm-gear, and is connected with the shaft *i* by means of the gears, worm, and worm-gear at *k*. Either the hand feed or the power feed is thrown in as desired by means of the hand wheels *l* and *m* and the pin *n*.

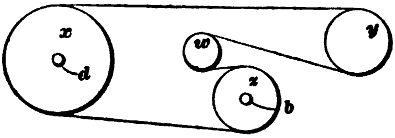


FIG. 3

In the larger sizes of this type of machine, a power traverse for the head is also furnished, taking its power from a screw in the radial arm *a*, which is connected with the vertical shaft *d* by a pair of bevel gears. The arm *a* and the slide *s* are raised by a screw in the column that runs in a nut attached to the slide between the guides of the upright. The power is transmitted to this screw through the gearing at *o*, and is controlled by the handle *p* on the lower end of the vertical rod *q*.

11. The work for which the radial drill is used is usually large and is generally supported on the foot-plate *r*, Fig. 2, which is finished and fitted with slots for T-head bolts. The table *s* is, however, provided for smaller pieces, or pieces that require side support. It is finished and has slots for supporting work on the top and sides. For light work, its own weight is sufficient to hold it in place, but for very heavy cuts, or where there is a tendency to tip, it should be bolted down. The work must always be so set that there will be no spring in the piece when the clamps are tightened, and should be so placed that as much work as possible may be done without resetting.

12. Gear-Driven Radial Drill.—The radial drill is often driven by shafts and gears instead of by belts. The power is transmitted directly from the main driving cone to a vertical shaft in the center of the column, and then, by means of gears at the top of the column, to a vertical shaft corresponding to *d*, Fig. 2. Another pair of bevel gears connect this shaft with a horizontal shaft on the radial arm, and the latter shaft in turn is geared to the spindle in the drilling head.

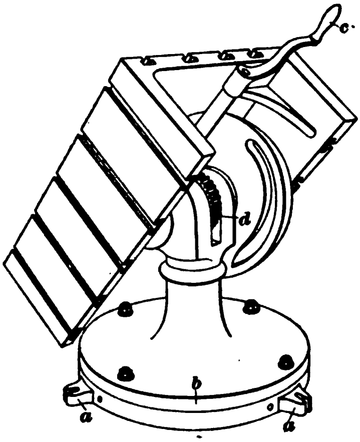


FIG. 4

13. Universal Table. The universal table, shown in Fig. 4, may be used on a radial drill to hold small pieces in which holes must be drilled at an angle. The table is bolted to the foot-plate by the lugs *a*, and may be turned about its center on the circle *b*. The top can be set at an angle, as shown, by turning the handle *c*, which drives a worm that meshes with the worm-gear *d*. Clamping bolts on each circle hold the table firmly in place when it has been adjusted to a desired position.

14. Universal Radial Drill.—Large work that cannot be supported on a universal table is drilled on a radial drill having an arm that can be rotated about its own center, and that is equipped with a head that can be thrown to any angle, as shown in Fig. 5. The rotation of the arm is obtained by pivoting it on the center of the shaft *c*. Such a machine is called a universal radial drill. The circle *a* on which the arm is rotated is graduated in degrees, and, as the arm may be turned through the entire circle, any adjustment to any angle may be made quickly and accurately. The circle *b* on the head is also graduated, thus furnishing a ready means of setting the spindle to any required angle. This machine differs in some details from the radial drills already described, but it has the same general construction.

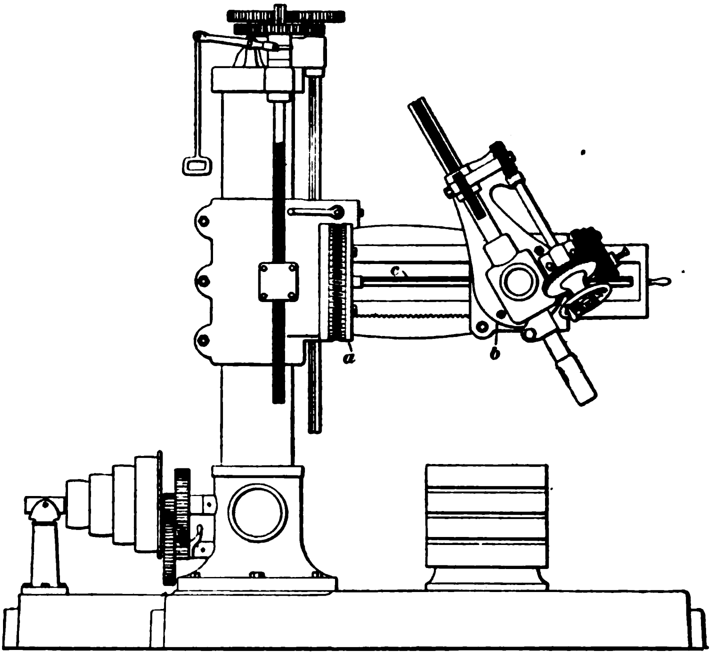


Fig. 5

15. **Change-Speed Gear-Box.**—The speed of a drill spindle may be altered by using a gear-box, as shown in Fig. 6. The gear-box consists of a casing *a* containing a set of change-speed gears, and is bolted to the base *b* of the drill. A belt drives the pulley *c*, and the coupling *d* connects the gear-box to the driving shaft of the machine. The speed is changed by

shifting the handle *e* up or down along the series of steps formed along the open side of the gear-box. When the gears are set for a given speed, the handle is held in place by a pin that fits a corresponding hole just below the step. In the gear-box shown, eight different speeds may be obtained. The positions of the handle for these speeds are numbered from 1 to 8, as

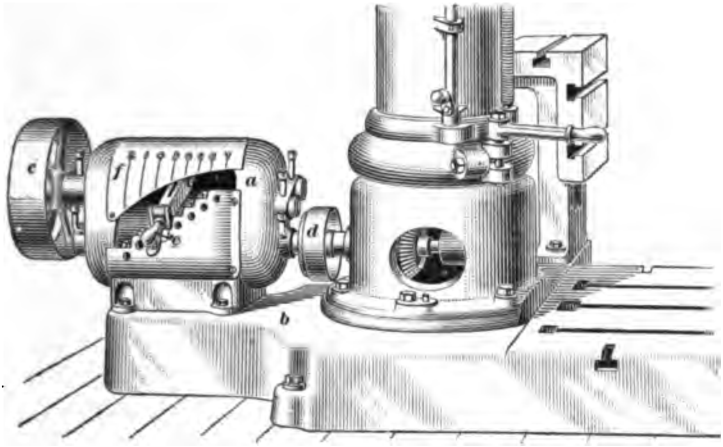


FIG. 6

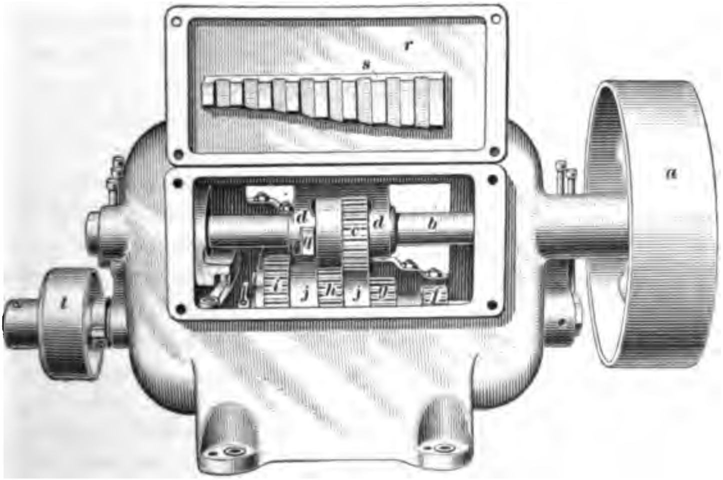


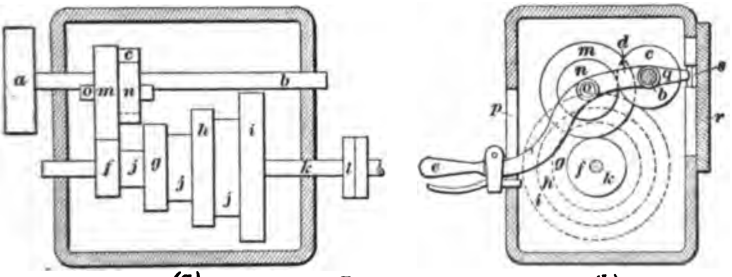
FIG. 7

shown on the plate *f*, the speed being greatest at position *1* and least at position *8*.

16. A back view of the gear-box, with the back cover removed, is shown in Fig. 7, and in Fig. 8 (*a*) and (*b*) are shown diagrams of the gear-arrangement as seen from the front and the end of the gear-box. The views in Fig. 8 do not give the actual shapes and proportions of the parts, but are merely intended to show the principle on which the gear-box acts. Those corresponding parts that can be seen in both Figs. 7 and 8 are given the same reference letters. The pulley *a* is fixed to a shaft *b* that runs from end to end of the gear-box. A pinion *c* is splined to the shaft, so that it can move freely along the shaft but must turn when the shaft turns. This pinion is held between the jaws *d* that form the upper end of the handle *e* by which the changes of speed are made. These jaws can both turn and slide on the shaft *b*.

17. In the lower part of the gear-box, Figs. 7 and 8, is a series of gears *f*, *g*, *h*, and *i* separated by blanks *j* and forming a cone. These gears are fixed on the shaft *k* that is connected by the coupling *l* to the driving shaft of the drill. The handle *e* near its middle carries a compound pinion consisting of two small gears *m* and *n* firmly fastened together. These gears are of different sizes and are fast to a shaft *o* that turns in bearings in the handle *e*. The smaller gear *n* of the compound pinion is always in mesh with the pinion *c* on the shaft *b*, and when the handle *e* is lifted and moved, the compound pinion and the pinion *c* are shifted in the same direction and at the same time. By shifting the handle sidewise in the slot in the front of the gear-box, the gear *m* or *n* of the compound pinion may be engaged with any one of the gears *f*, *g*, *h*, and *i*, and thus eight different speeds may be obtained.

18. In the position shown in Fig. 8, the gear-box is set for the greatest speed, corresponding to position *1* on the plate *f*, Fig. 6. The pinion *m*, Fig. 8, is in mesh with the gear *f* and the shaft *k* is driven at the greatest speed that can be obtained with this gear-box. If the handle is moved one step to the left, the pinion *n* will engage with the gear *f* and the shaft *k* will turn slower. If the handle is shifted one step to the right from the position shown, the pinion *n* will mesh with the gear *g* and a still slower speed will result, because the gear *g* is larger than the gear *f*. To make certain that the gears are in the correct position to engage properly, the handle has a projecting toe *q* at the back, and on the back cover-plate *r* is a rack *s* with eight slots. The handle cannot be lowered to engage the gears until the toe *q* is directly opposite one of these slots. The toe, the rack, and the slots are clearly shown in Fig. 7, also.



(a) FIG. 8 (b)

SENSITIVE DRILLS

19. Construction of Sensitive Drill.—In a machine shop, there is a large amount of light work on which it is necessary to use drills that are too small to be run at the required speeds in heavy drilling machines. This has led to the development of a light and sensitive type of drilling machine called the sensitive drill, one form of which is shown in Fig. 9. The power is transmitted directly to the spindle by belts, and the speed is varied by the use of cone pulleys. The feed is obtained by hand by turning the lever or bar at the outer end of the head *c*. The lever is fixed to a shaft that carries a pinion that meshes with a rack cut in the sleeve of the spindle. This is the most sensitive arrangement in use, any variation in the working conditions of the drill point being readily felt by the hand on the lever. The table *a* of the drill shown has no vertical adjustment, but may be swung about the center of the post, out of the way of the center line of the spindle, so as to allow long pieces to be set on the lower table *b*. The lower table and the lower spindle head *c* are both adjustable vertically, thus allowing pieces of greatly varying lengths to be drilled in the machine.

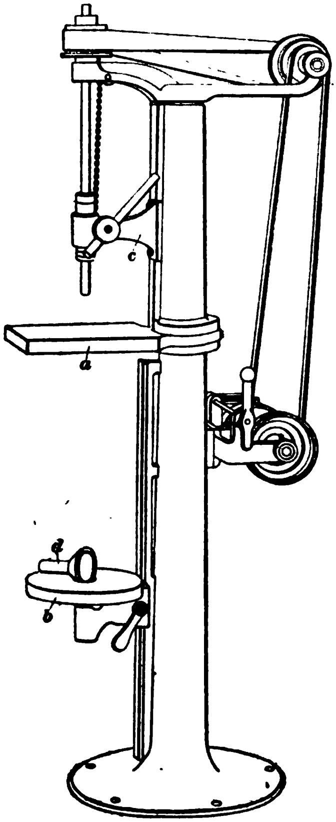


FIG. 9

20. Center Drilling With Sensitive Drill.—The sensitive drill is used largely for center drilling in shops where a special machine for this purpose is not available. The funnel-shaped piece *d*, Fig. 9, commonly called a *cup center*, is a special device for centering the lower end of a shaft that has been cut off square. The shank is set in a hole in the center of the lower table *b*, the center line of which coincides with the center line of the spindle. The top of the cup *d* is made a perfect internal cone, with its axis in the center of rotation of the spindle. A shaft that is set in this cup and is held with its center under the drill at the upper end will, therefore, be correctly centered.

21. Sensitive Radial Drill.—The larger sensitive radial drill has been brought into use to provide a simple machine that can be operated quickly and easily on work too large for the sensitive drill and too small to be done economically on the drill press or the large radial drill. It is designed to give the required speed for the smallest drills and to have power and stiffness enough to drill holes $\frac{3}{4}$ inch in diameter. The form shown in Fig. 10 consists of a floor plate *a* that carries the column *b* and the bracket to support the driving pulley *c* and the loose pulley *d*. The column carries the radial arm *e* at the top and the work table *f* at the middle. The rack *g* fits in a slot in the table and is held between shoulders on the column, so that

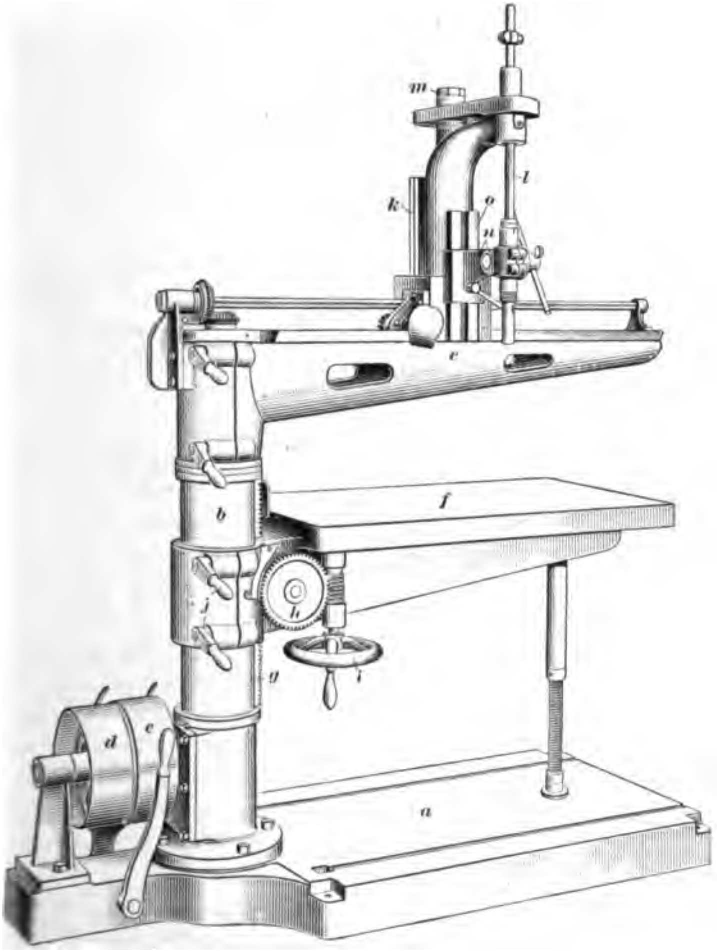


FIG. 10

it can swing around the column with the table but cannot move up or down. The rack meshes with a pinion on the same shaft as the worm-wheel *h*, and when the hand wheel *i* is turned, the table is raised or lowered. The handles *j* are turned to clamp the table tightly on the column, and similar handles are used to clamp the radial arm to the column. The drilling head *k* may be moved along the slide on top of the arm *e* and clamped at any point. The spindle *l* is driven by belt or by chain from the shaft *m*, which is connected by bevel gears and shafts to the driving pulley. The drill-spindle arm *n* is adjustable vertically on the slide *o*. If desired, the table may be swung to one side, and the work may be secured to the floor plate by **T** bolts in the slots shown.

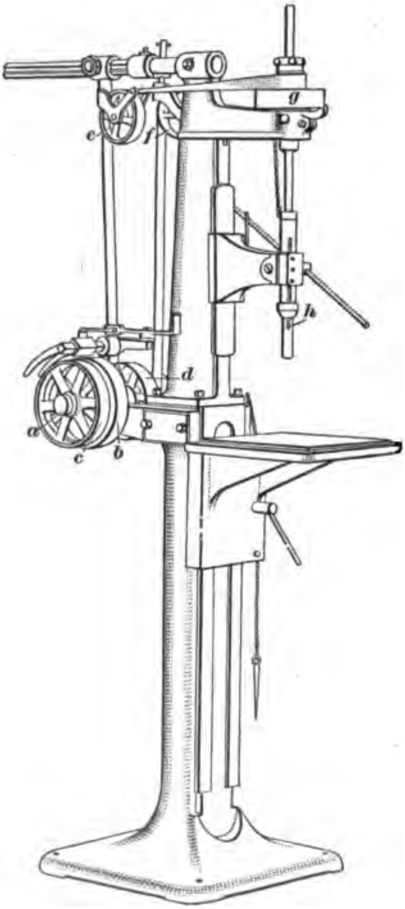


FIG. 11

22. High-Speed Sensitive Drill.—A high-speed sensitive drill with ball bearings on the spindle is shown in Fig. 11. The driving shaft *a* carries the tight and loose pulleys *b* and *c* at one end and the cone pulley *d* at the other. This cone pulley has two steps and from it a belt passes over the adjustable guide pulleys *e* and *f* to a similar cone pulley *g* of different size on the spindle *h*. Thus, by arranging the belt on different pulleys, four different speeds of the spindle may be obtained. The pulleys *b* and *c* are of slightly different sizes and the loose pulley *c* is made with one edge beveled outwards to the diameter of the tight pulley. Thus, when the belt is running on the loose pulley, it is slack, and therefore does not wear much or stretch; but when it is shifted to the tight pulley, it is stretched and grips the pulley, thus insuring little slip and good driving power. The same construction is used in Fig. 10.

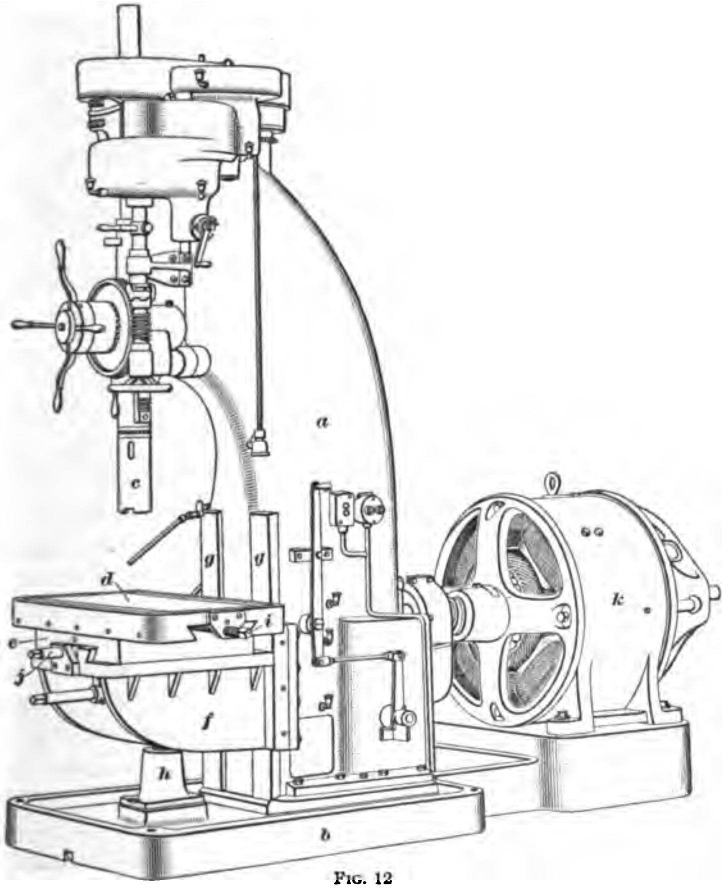


FIG. 12

23. Heavy-Duty High-Speed Drill.—Drilling machines of the older types could not be used to advantage at high speeds because of the vibrations set up and also because they would spring under the pressure of the heavy feeds when using alloy-steel drills. The heavy-duty high-speed drill, one form of which is shown in Fig. 12, was designed to overcome these disadvantages. It consists of a heavy cast-iron frame *a* of box section bolted to a floor plate *b*. The front of the frame carries the spindle *c*, the back gearing, and the gearing for driving and feeding the spindle. The table *d* is carried on a saddle *e* that is supported by the bracket *f*. This bracket may be moved up or down on the slides *g* on the column, and is supported by a screw jack *h*. The table and the saddle may be moved crosswise by turning the screws *i* and *j*. The machine is driven by an electric motor *k* through back gearing, so that a wide range of speeds may be obtained for the spindle. It is therefore suitable for a variety of drilling operations and also for special work, such as milling and boring.

OTHER TYPES OF DRILLS

24. Multiple-Spindle Drill.—The tendency toward specialization has brought about the use of tools especially designed to save time and prevent error in the duplicating of parts. It has been found that in drilling a large number of holes in one piece, time may be saved by using multiple-spindle drilling machines sometimes called *gang drills*. The term gang drill is also applied to the practice of arranging two or more similar single-spindle drills side by side so that they are operated as a single machine. The multiple-spindle drill shown in Fig. 13 has six spindles in six heads carried on a single crossrail. The spindles are driven from the same shaft *a* by worms and worm-gears *b*, the shaft *a* connecting with the driving cone *g* through the gears *h* and *i*. The motion for the feed is taken from the shaft *c*, running in the cross-rail, and is transmitted to each spindle by gearing and clutches at *d*, the feed-shaft *c* being driven from the main shaft *a* by a belt on the cone pulleys *e* and *f*, which also furnish the variable feed.

25. The table on the machine shown in Fig. 13 is not movable, and only work of a moderate depth can be drilled in it. This same general type of machine is, however, frequently made with an adjustable table. The spindle heads can be moved along the cross-rail and set any distance apart, within the range of the machine, and any number of holes from one to six may be drilled at the same time. This type of machine is used principally for plate work, structural iron, and other light work requiring a large number of holes in a straight line. Modified forms are used largely for drilling locomotive frames and

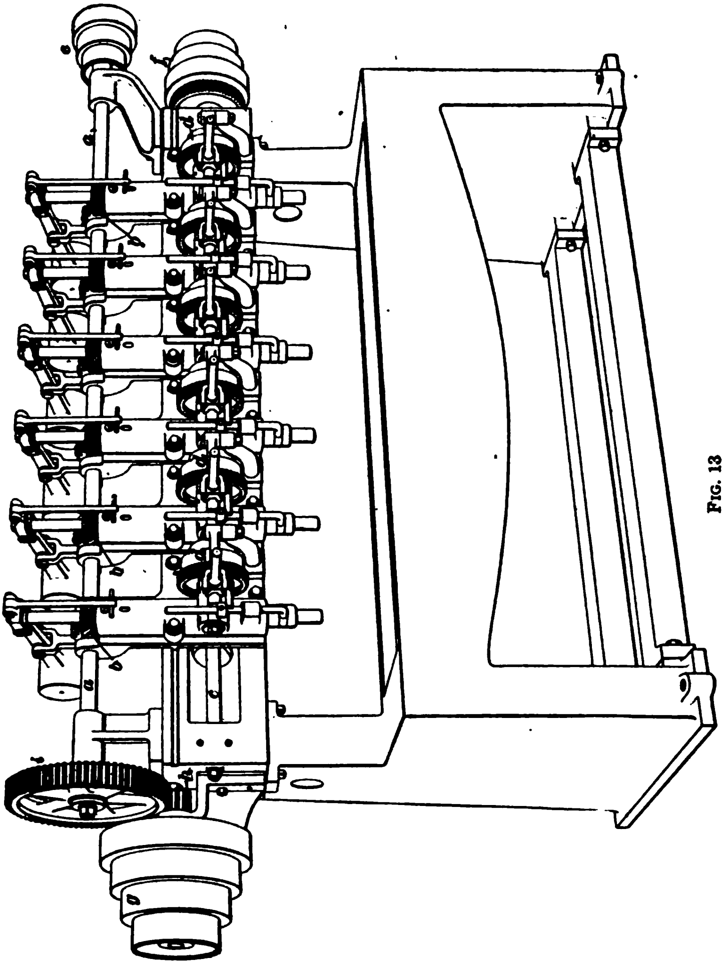


FIG. 13

bridge chords, and for tapping nuts in large numbers in bolt and nut factories.

26. **Universal Adjustable Spindles.**—Multiple-spindle drills are frequently made with universal adjustable spindles. The universal joints allow the spindles to be moved in and out as well as along the cross-rail. With this arrangement, holes

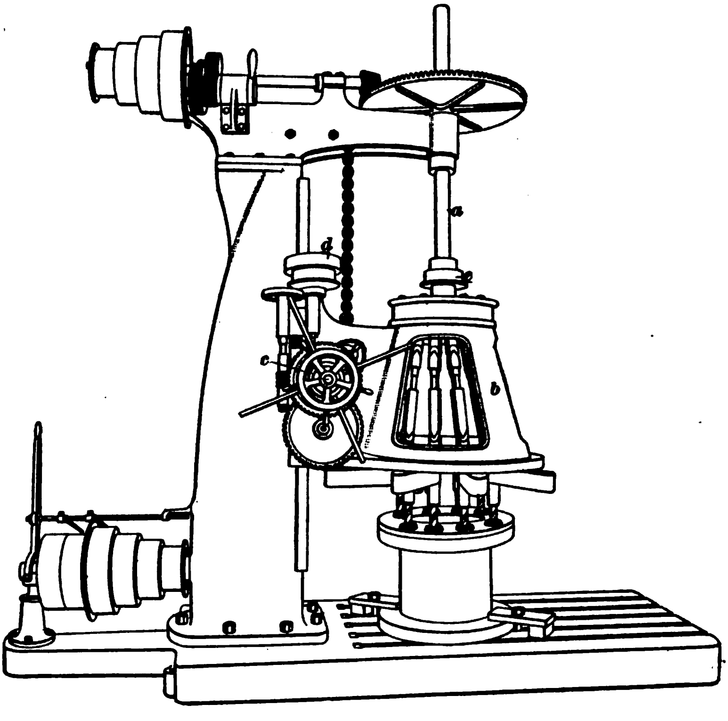


Fig. 14

that are not in line with one another may be drilled at one setting; or, if the holes are to be tapped or reamed and are far enough apart, half of the spindles may be equipped with drills and the other half with taps or reamers, so that when the holes are drilled the piece may be moved to the other set of spindles and finished without taking it off the machine. Jigs should always be used in drilling with universal-joint spindles, as the short lower bearing is liable to become slightly worn or may not be in perfect adjustment, thus introducing inaccuracies. A well-constructed jig guides the drill perfectly and avoids this danger.

27. **Vertical Flange-Drilling Machine.**—A very useful multiple-spindle drill is shown in Fig. 14. The spindles, which are arranged about the center of the main driving spindle *a*, are all equipped with universal joints, and each one moves independently of the others. This enables the machine to drill as many holes as there are spindles. The spindles may be arranged in one or more circles or set irregularly, as desired.

28. The machine shown in Fig. 14 is designed for drilling engine cylinders, pipe flanges, valve bodies, etc., but it may be used for almost any work where a regular or irregular grouping of drills is desirable. The illustration shows a piece of flanged pipe clamped on the drill table with jig attached and drills inserted, ready for drilling. The power is transmitted to the spindles by a spur gear on the main spindle *a* and a small pinion on the upper end of each of the drill spindles enclosed in the upper part of the head *b*. The drill spindles are held vertically in both the upper and lower bearings. The feed is obtained by lowering the entire head *b*, which may be done either by means of the pilot wheel *c* or by power by means of a belt running on the cone pulleys *d* and *e*. The smaller machines usually have the drilling head stationary, and the feed is obtained by a vertical movement of the work table.

29. **Horizontal Flange-Drilling Machine.**—Multiple-spindle drilling machines with two heads set horizontally on a long bed, intended especially for drilling the two ends of engine cylinders, pipes, etc., at the same time, are also in use. The construction of the heads is practically the same as that shown in Fig. 14, the only difference being that they are placed horizontally on the bed. The work is held on a table between the two heads.

DRILLING-MACHINE OPERATIONS

DRILLING, REAMING, AND TAPPING

DRILLING

30. Laying Out.—In many modern machine shops, the laying out of all the work is done in a special department and the work is sent to the machine tools ready for the operation. For the drilling machine, the center of the required hole is first punch-marked. Then a circle having a diameter equal to that of the hole is scribed about it and light prick-punch marks are put at intervals about the circumference, as shown in Fig. 15. The diameter and character of the hole are also marked, usually with chalk. Thus, the note 1½″ *R* indicates that a 1½-inch reamed hole is required.

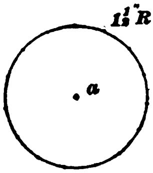


FIG. 15

31. Preparation for Drilling.—When the work reaches the drill, the operator enlarges the center *a*, Fig. 15, with a large center punch, to form a guide for the drill point when beginning the cut. It is practically impossible to start the drill in the center of the hole without the assistance of this deep center mark. The piece is now clamped on the table as conditions require. The drill table is then swung about and adjusted until the center mark stands exactly under the drill point, the drill having been run down to make sure that the point coincides with the center. The table is then clamped to prevent any motion while drilling, the machine is started, and the drill is fed into the work.

32. Starting the Drill.—When the drill has commenced cutting, any unevenness, or varying hardness of the metal, or imperfection in the drill point, tends to carry the point away from the true center of the hole. As the drill runs down, making a conical hole as shown in Fig. 16, any tendency away from the center may be observed by raising the drill point slightly and blowing or brushing away the chips. If the circle made by the drill is not concentric with the circle of punch marks, the drill has run off from the desired center, and must be brought back. A drawing chisel, shown in Fig. 17, is used for this purpose. This is simply a narrow round-nosed chisel with which the metal is cut away on the side toward which the drill point is to be drawn, as shown in Fig. 18. The cutting should be done quite near the center, as a given amount of metal removed there will draw the drill farther than when the cutting is done near the circumference. The drill is again lowered and the result is observed. If the circle should not be concentric, the chisel is again used and the drill tried; this operation is repeated until the hole coincides exactly with the circle when the drill has entered to its full diameter. If the drill has run badly to one side as when striking a blow hole, it is often necessary to chip from three to five cuts side by side to get the drill back concentric with the circle. The punch marks are cut away equally all around the circumference when the drill has been properly started. The drill is then fed through the piece, or to the desired depth, either by hand or by power, and is backed out by hand.

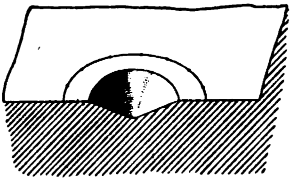


FIG. 16

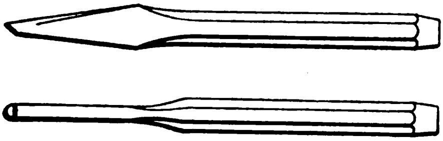


FIG. 17

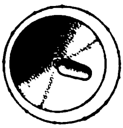


FIG. 18

33. Advantages of Power Feed.—All drill presses of the heavier types should be so constructed that either hand or power feed may be used. In light work, enough pressure can be furnished by hand to cause the drill to cut to its full capacity, but in the heavier work a greater pressure is needed. It is contended by some that the average workman will accomplish more by feeding by hand than by using a power feed, as the tendency seems to be to set the feed at its finest rate, although most drill presses are provided with gearing that will furnish two or more rates. This is the fault of the operator and not of the method. The power feed should be so set that the drill will work up to its limit, which it is impossible with a hand feed when large drills are used.

34. The power feed has several advantages over the hand feed for large sizes of drills. With careless hand feed, the drill may run forwards as the point emerges from the material, causing a rough hole and damage to the drill. The same is true when it enters a blow hole. When drilling flanges, the drill frequently breaks through on one side, and, when the cutting edges stand at a certain angle, the drill runs forwards easily and the next instant takes a heavy cut on one side only. It is evident that this condition will sooner or later result in a damaged drill. With the power feed, all this is avoided, as the drill has a fixed rate of advance. When using the power feed, care must be taken to see that the drill is in proper working condition.

35. Lead Holes.—If the machine has not power enough to drill the full-sized hole in one operation, the hole should be started with a full-sized drill, and drilled about $\frac{1}{4}$ inch deep, central with the laying-out circle. The full-sized drill should then be taken out and replaced by a small drill having a diameter equal to about twice the width of the scraping edge of the large drill. The small drill should be used to drill a lead hole at the center of the hole already started, and should be fed to the desired depth. It should then be replaced by the large drill and the drilling of the hole should be completed. The lead hole removes the metal at the center, so that the scraping edge of the large drill does no cutting. All of the pressure and the cutting then comes on the cutting edges. Sometimes a lead hole is drilled ahead of a drill that is required to cut exactly to its own size.

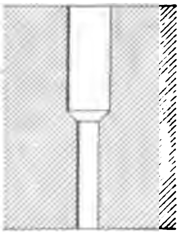


FIG. 19

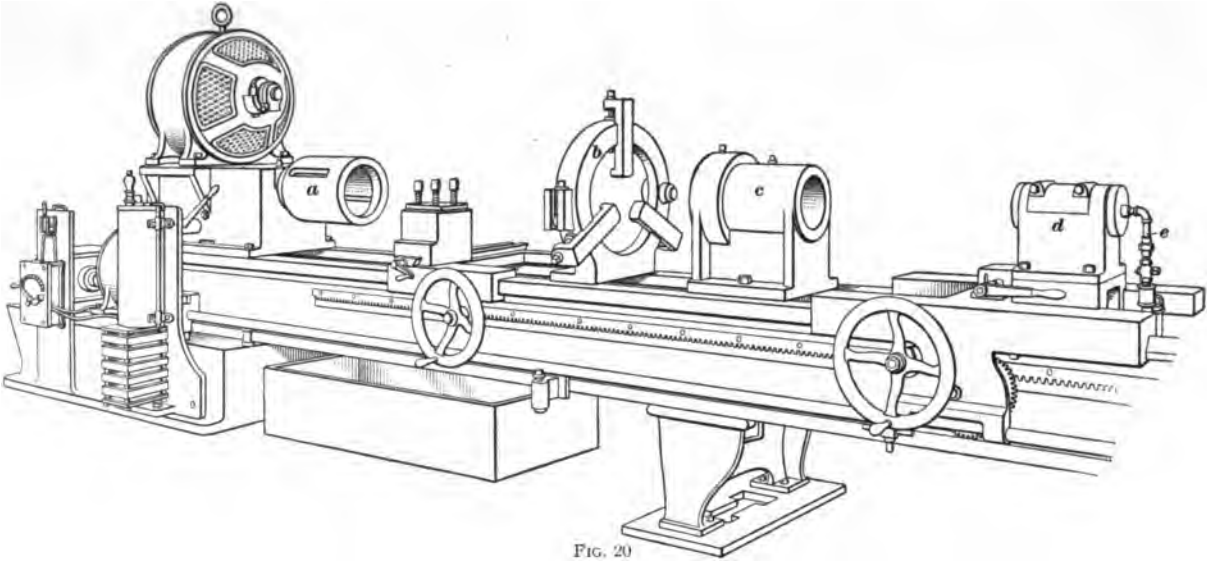


FIG. 20

36. Drilling Deep Holes.—When drilling deep holes through a piece of work, it may be necessary to go deeper than the length of the flutes in the drill of the required size. If the hole is not too deep, the drill may be backed out and the hole cleaned at short intervals. When the hole is very deep, however, time may be saved by running the drill down as far as the chips will discharge, then drilling the remaining depth with a smaller drill, making a hole as shown in Fig. 19. The first drill is then put back into the machine and the entire hole drilled to the full size. The second drill must be small enough so that the chips can work out around it, but must not be so small that the chips made by the larger drill that follows it cannot drop out freely at the bottom. In one instance, where a $1\frac{15}{16}$-inch hole was drilled through 26 inches of solid cast iron, a $1\frac{1}{4}$-inch drill was employed to drill the small hole and gave good results.

37. Drilling holes in solid stock to form rifle and gun barrels, hollow spindles, and similar work is done in special machines of the horizontal type shown in Fig. 20. The work is held and driven by the chuck *a* on the live, or rotating, spindle, and the outer end is supported in the steady rest *b* clamped to the bed. The drill tip, or point, *a*, Fig. 21, is secured to a long holder having an oil groove to match the oil groove *b* cut in the top. The drill has but one cutting edge *c*, and a hole is usually started for it with a short drill. Drilling is performed by feeding the drill into the work through the rest *c*, Fig. 20, by means of the tail-stock *d*. The oil pipe *e* furnishes a constant supply of oil at high pressure, which is delivered under the cutting edge *c*, Fig. 21, and escapes through the flute *d*, carrying the chips or cuttings with it. The drill point is ground in a series of steps, to break up the chips and make them easier to discharge.

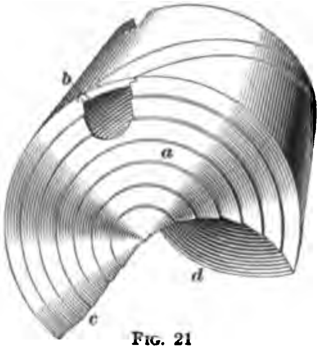


FIG. 21

38. Drilling Holes to be Tapped for Pipe.—Pipe taps, as shown in Fig. 22 (*a*), have a standard taper of ¾ inch per foot. The tapping holes for pipe sizes are drilled to the size of the small end of the pipe tap, which is then run into the hole to the required depth to give the correct length of thread. If the pipe tap is required to take out too much stock from the large end of the hole, it is sometimes better to remove the surplus stock with a taper reamer like that shown in (*b*), so that all the tap has to do is to cut the depth of its thread. This makes the tapping process much easier. Straight threads are sometimes required on pipes, and the parts into which the pipes are screwed are threaded with straight pipe taps like that shown in (*c*). The straight pipe tap has the same number of threads per inch as the taper pipe tap of similar size; otherwise, it is simply a plug tap. Table I, at the end of this Section, gives the various dimensions of standard pipe for steam, gas, and water, and shows the sizes of holes to be tapped to fit standard pipe.

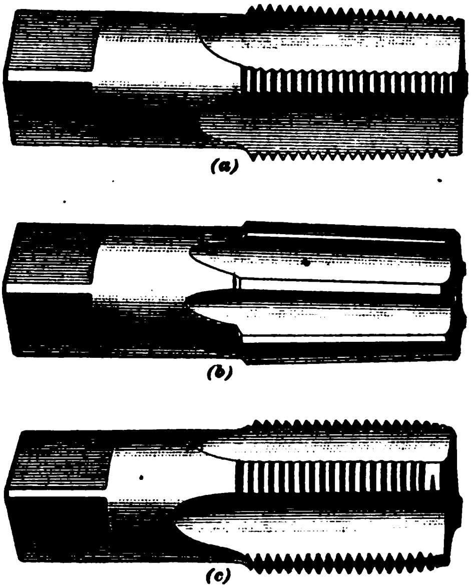

(*a*)
(*b*)
(*c*)

FIG. 22

REAMING

39. Methods of Reaming.—Reaming consists in truing a hole by running a reamer through it. The hole has been drilled or bored, and as it is a matter of economy to do as much work as possible at the same setting, the reaming is done in the same machine that was used for the drilling or boring. The machine reamer is made with a shank that can be used in a drill press, but is run at a slower speed than the drill and is carefully fed by hand or by power. For very accurate work, the hand reamer is used and is operated by hand, but it may be guided by a center in the drill spindle, as shown in Fig. 23. The reamer *a* is turned with a wrench and is followed up by the center *b*, which also furnishes the necessary pressure to give the feed.

40. Care Necessary in Reaming.—Reaming should be done with the greatest care. Undue forcing of the reamer, any side pressure, or any irregular or jerking motion, tends to injure both the reamer and the hole. A very steady and comparatively slow motion with rapid feed gives the best results. In some cases, the weight of the reamer and the wrench is sufficient to furnish the feed, although some additional pressure is usually necessary. The allowance for hand reaming is usually from 3 to 5 thousandths of an inch.

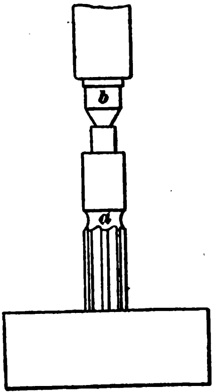


FIG. 23

Structural iron work is often reamed with portable drilling machines. The parts are usually punched as closely as possible to size and then brought into position. The holes do not usually line very well, so a bridge reamer having a taper for a distance of about 1½ inches is placed in a portable drill and fed rapidly through the holes. The tapered part takes out the most of the stock and the parallel portion above sizes the holes. The machine is often suspended from a carrier rail and counterweighted to make the work of handling it easier.

41. Rose Reaming.—Adjoining parts must often be drilled separately, especially when the pieces are large or when it is impossible to drill a continuous hole. A case of the second kind is shown in Fig. 24, in which the two flanges *a* and *b* are to be drilled and joined by bolts *c*. The holes are first laid out, as accurately as possible, on the faces of both parts. Then the holes *d* in the part *a* are drilled and reamed to size with a power drill. The holes *e* in the part *b* are drilled from $\frac{1}{16}$ to $\frac{1}{8}$ inch smaller in diameter than the holes *d*. The flanges *a* and *b* are next clamped together accurately and the holes *e* are reamed to size by a rose reamer that is passed through the holes *d*. The rose reamer fits the holes *d* accurately and is run through by a ratchet. It may be followed by a hand reamer if a very accurate hole is required. The rose reamer must be fed much slower than the machine reamer, as it cuts only on the end, and removes a large amount of metal.

42. Machine Reaming.—After a hole has been drilled, it is reamed by replacing the drill with a machine reamer and feeding the latter through the hole at one speed slower than the drill. This one speed slower is obtained by moving the belt to the next smaller step on the lower cone pulley of the drill press. The cut of the reamer is light, and the feed should be as fast as possible, to save wear on the reamer.

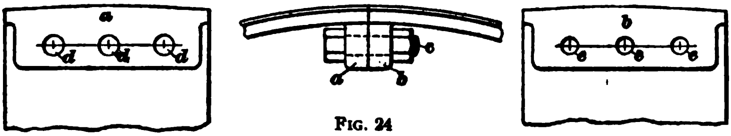


FIG. 24

A tapered hole that is to be reamed by machine is first drilled to the size of the small end of the reamer, which is placed in the spindle or the chuck and is fed into the hole by lever feed, if possible, or else by hand. Plenty of oil is used during cutting, and the reamer is withdrawn and cleaned before the flutes fill with chips. The cleaning operation is repeated as often as may be necessary, until the hole is reamed to the required depth or size. If the chips are allowed to gather in the flutes, the reamer will stick and be broken.

TAPPING

43. Forms of Taps Used.—The forms of taps used in the drilling machine are the same as those used in handwork. The shank is usually made with a square end, or of some other form adapted for chucks or sockets. In ordinary machine tapping, a taper tap gives the best results. When the thread runs through the material, the tap is run either entirely through or until a thread of the full diameter is formed. When the hole does not run through and the thread must run as near the bottom as possible, the taper tap is used to start the thread, and is followed by a plug tap and a bottoming tap. As in reaming, the speed of the tapping spindle must be slow, and after the tap is started no pressure should be put on it by the feeding device. The tap should be perfectly free to take its own feed.

44. **Correct Size of Tapping Hole.**—It is very important, when tapping, that the hole is so drilled that a full thread will be formed without removing an excessive amount of metal. This is done by using a tap drill having a diameter equal to the diameter of the tap at the bottom of its thread. When the hole is drilled too small, the tap is very hard to start, and when it is started, the work is so heavy that the tap is often damaged; also, the amount of time and energy required is far greater than is necessary when the hole is of proper size. It is claimed by some, however, that the hole should be drilled larger for cast iron than for wrought iron and steel, and that a thread about three-quarters full in the case of cast iron is stronger than a full thread, owing to the danger of crushing the points of the thread.

A hole that is too large is equally objectionable, as the threads will not be of the full depth, and will, therefore, be imperfect and weak. The tap runs very easily, however, when the hole is large, and for this reason there is a tendency toward making it large, even at some sacrifice in the strength of the thread. This should, however, never be permitted, as the perfect form of the thread should be maintained under all conditions. Table II, at the end of this Section, gives the sizes of tap drills to be used for taps having V threads; Table III gives the sizes of tap drills for machine-screw taps; and Table IV gives the sizes of tap drills for taps having United States standard threads.

COUNTERSINKING, COUNTERBORING, FACING, AND CENTER DRILLING

45. Countersinking.—Countersinks used for accurate work are provided with guides and have but little clearance so that they will not chatter. The most common form of countersink has an included angle of 72°, and is used for flat-head screws. It is simply fed into the work so that the top of the screw head comes flush with the surface of the work. The 60° countersink is used for center holes in lathe work. The 90° countersink is used for valve seats, to remove sharp corners from the ends of holes, and to enlarge holes for riveting. Other angles are used for special work.

46. Facing.—The guide end of the facing bar is well oiled, and the cutter is fed carefully to the cut until the surface is true or until the required depth is reached. If a very heavy facing cut is to be made, it is customary to make a notched roughing cutter remove most of the stock and to use a finishing cutter to complete the work.

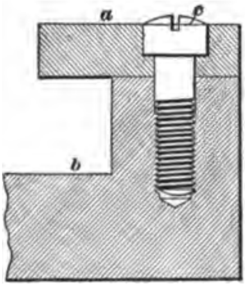


FIG. 25

47. Center Drilling.—The sensitive drill is largely used for center drilling. The piece is first punch-marked to locate the center holes correctly. The lower end is then placed in a cup center or on a conical center and a center drill is used to drill a clearance hole to a depth somewhat greater than that of the required reamed part. The piece is then reversed and the other end is drilled. A center reamer is then substituted for the drill, the speed is reduced, and the holes are reamed to the required size, which should always be in proportion to the size of the work. Most work is drilled and reamed at one operation by the use of a double center drill or a combined drill and reamer.

48. Counterboring.—Suppose that the gib *a*, Fig. 25, is to be secured to the slide *b* by means of ½-inch round-head screws *c*. The holes are first laid out on the gib, which is clamped securely in position on the slide. A $\frac{13}{32}$-inch tap drill is then used to drill through the gib, and all of the holes are drilled to the required depth in the slide. The gib is then removed from the slide and a head counterbore is substituted for the drill. The guide of the head counterbore is the same size as the tap drill and the holes must be counterbored to the right depth for the screw heads. If flat filister-head screws are used, the counterboring should be so deep that the top of the screw is even with the surface of the work; but the round part of a filister-head screw should project above the work. The body counterbore, which also has a guide the size of the tap drill and a body the size of the screw, is next run through the gib, so that the screw will slide freely through it. The body counterbore is then run into the lower hole for a distance equal to about two threads, and this leaves the hole ready for tapping.

49. **Drill-Press Depth Indicators.**—Where holes must be drilled or enlarged to certain depths, stops or depth indicators of various designs are used on the column, sleeve, spindle, or sleeve-pinion shaft to indicate when the required depths of cut have been reached. If the head on the column is fed downwards, a clamp with an adjusting screw is used below the head. The clamp is first placed in position and the adjusting screw is set so that the head can be fed down to it, but no farther. All the other holes can be drilled or enlarged only to that depth. Some drills are provided with a clamp and an adjusting screw that can be secured on the spindle sleeve above the arm. This stops downward movement when the adjusting screw reaches the arm. Sometimes the sleeve is graduated or has a steel rule so placed that any depth is indicated by the coincidence of lines.

A disk indicator is sometimes put on the feed-pinion shaft. It consists of a stationary and a rotating disk, and the latter is graduated along the edge with graduations that indicate thirty-seconds of an inch of downward movement of the drill spindle. The rotating disk is set with its zero mark in line with the zero mark on the stationary disk and is clamped to the feed-pinion shaft. Then, as the drill is fed downwards, it will turn and indicate the depth of the hole.

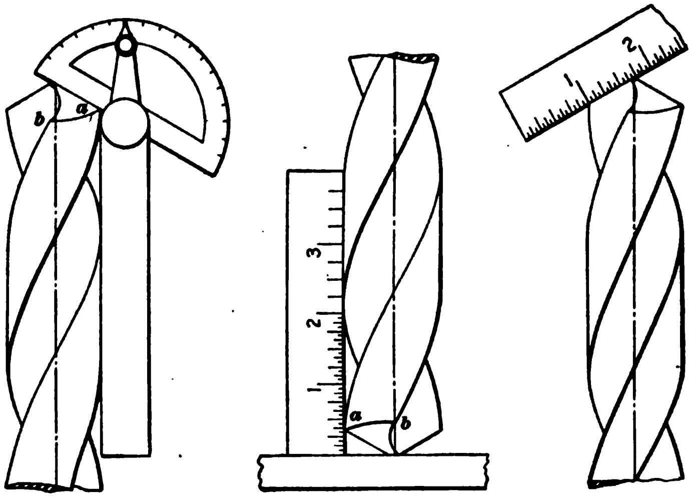
LUBRICANTS

50. When drilling cast iron and brass, no lubrication is necessary; in fact, it retards the work in the case of cast iron. Wrought iron and steel, however, always require lubrication. When tapping, some form of lubricant should be used with all metals, including cast iron. Usually, the lubricant is dropped on the cutting edges with an ordinary oil can; but in multiple-spindle machines, and occasionally in single-spindle machines, a tank, with a tube leading to the tool, is attached to the machine frame, and the flow is controlled by means of a valve in the tube. A small pump carries the lubricant from the table of the machine back to the tank, thus providing a means of using the same lubricant over and over again, and of flooding the cutting edges without undue waste of the lubricating material. Table V, at the end of this Section, gives a list of the lubricants to be used for different operations on different materials, as suggested by the Morse Twist Drill and Machine Company. The mixture mentioned in this table is made of one-third crude petroleum and two-thirds lard oil; and when oil is mentioned, sperm or lard oil is to be used, sperm being preferable. When two lubricants are mentioned, the first is preferred. No lubricant is used in drilling and reaming aluminum, but vaseline or kerosene may be used as a lubricant when tapping this metal.

DRILL GRINDING

51. Hand Grinding of Drills.—When grinding a drill by hand, it is grasped lightly in both hands, with the palms up, the right hand being near the point and the left hand near the shank. The back of the right hand is then rested on the grinder rest and the full length of one cutting edge is brought into contact with the wheel. The shank is then lowered, which raises the cutting edge and grinds the clearance on the drill. This is repeated until the first edge is sharp. The drill is then given a half-turn, without changing the position of the hands, and the other side is ground in the same manner. If the hands are kept in the same relative positions when grinding both lips, the angles will be the same. These operations are repeated until the drill is sharp. The grinding may be tested by eye by holding the drill with the point up and comparing the angles and lengths of the cutting edges by looking toward the light. Any difference will be noticed readily after a little experience, and may be corrected by repeated grinding.

52. Testing Form of Drill Point.—The similarity of the two cutting edges may be tested, when grinding the drill, in the following manner: The drill is placed in the spindle and fed into a piece of scrap cast iron until it cuts the full size and the hole is about $\frac{1}{32}$ inch below the top surface. The machine is then stopped while the feed is still on, so that the chips will not be cut off, and the drill is raised. If the cutting edges are alike, the chip cut by each lip will extend from the center clear to the circumference of the hole, and the drill will cut its own size. If, however, one chip is complete and the other does not reach the circumference, it shows that the latter side of the drill has a shorter cutting edge, and grinding should be continued until the chip is cut evenly to the circumference by each lip.

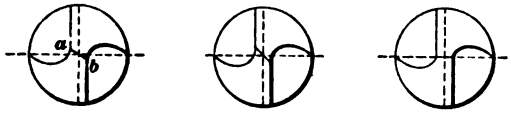


(a) (b) (c)

Fig. 26

53. The correctness of shape of the point of a twist drill may also be tested by a gauge, or a protractor, set at the required angle, and applied to the side and edge of the drill, as shown in Fig. 26 (*a*). By turning the drill so as to bring the protractor from the edge *a* to the heel *b*, the clearance angle may be observed, and in this way the two sides may be compared. Another method often used is illustrated in (*b*). The point of the drill is set on a flat surface and a scale is held upright against its side, as shown. The heights of the corners *a* from the point are thus measured. If the two sides are alike, the drill is turned and the heights of the corners *b* are measured, and if these are the same, the clearance angles are equal. The length of the cutting edges may also be tested by applying a steel rule, as shown in (*c*), the portion graduated to thirty-seconds or sixty-fourths, being used. Grinding should be repeated until the two cutting edges measure the same length.

54. Angle and Length of Scraping Edge.—The clearance angle determines the angle of the line *a b*, Fig. 27, representing the scraping edge. This illustration shows about the correct angle. When the angle is too small, as in (*b*), the scraping edge is too long and greater pressure is required to feed the drill. If the angle of the scraping edge is too great, as in (*c*), there is no clearance at the back of the cutting edges. It is then almost impossible to feed the drill into the work, and if much pressure is applied, the drill is likely to split. The center of the drill is made thicker as it approaches the shank, to strengthen the drill, and so, as the drill is ground shorter, the length of the scraping edge increases. When this increase becomes too great, the drill point should be thinned by grinding out the flutes until the point is reduced to its original thickness. The shape of the flutes should be kept the same as before.



(*a*) (*b*) (*c*)

Fig. 27

55. Grinding Drills to Cut Larger Holes.—It is frequently necessary to fasten machine parts together by pins cut from wire rods and driven into holes drilled in the parts. It is not customary to fit the pins to the holes but to drill the holes to fit the size of wire available. This is done by selecting a drill usually slightly smaller than the wire and grinding it with one cutting edge longer than the other, so that it will cut enough larger than its size to allow the pins to be driven in with the required degree of tightness. If care is taken in grinding drills, both driving and loose fits may easily be provided for by regrinding the same drill.

DRILLING JIGS AND FIXTURES

DRILLING JIGS

56. Drilling Duplicate Pieces.—Duplicate pieces may be drilled by the use of drilling jigs. A **drilling jig** is a device that may be temporarily attached to the work, to act as a guide for the drill in any desired position. The drill is guided by steel bushings placed over the positions of the required holes. In this way a large amount of time otherwise devoted to laying out may be saved, and when the jig is well made, a degree of accuracy may be attained that is impossible by any other means. The economy of such a device depends on the number of pieces to be drilled and the cost of the jig.

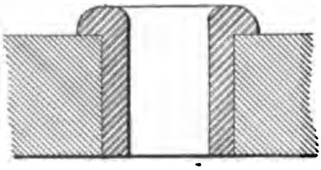


FIG. 28

57. Construction of Drilling Jig.—The body of the jig is usually made of cast iron, but in order to prevent undue wear of the holes, hardened-steel bushings that fit both the jig and the drill snugly are inserted. These bushings are generally made with a shoulder, as shown in Fig. 28, and with the inner corner rounded, to avoid damage to the drill when entering. When jigs are used from both sides, the bushings are set as in Fig. 29, the inside corners being rounded on both ends.

When drilling two adjacent parts, as, for instance, the flange and the head of a cylinder, the head may be drilled first, and may then be used as a jig for drilling the cylinder, or as a templet for marking the holes. When a large number of duplicates are to be made, however, it is better to use a jig for both the cylinder and the head.

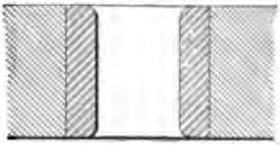


FIG. 29

58. Jig for Drilling Flanges With Regularly Spaced Holes.—In Fig. 30 is illustrated a flange *a* and a jig *b* of the form that is very generally used for this class of work. A lip *c* on the circumference of the jig fits the flange and holds the jig central. When the jig is in the desired position, a clamp is applied to keep it in place while the drilling is being done. When the adjoining flange or head is of the same diameter and the holes are equally spaced on the same circle, it may be drilled with the same jig, by merely turning the jig over, and the holes will be in line when the two parts are put together.

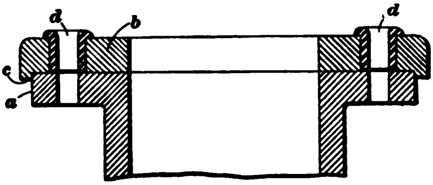


FIG. 30

59. Jig for Drilling Flanges With Irregularly Spaced Holes.—When the holes are not regularly spaced, they cannot be drilled to match by turning the jig over; consequently, it is necessary to make the jig with a lip on each side and with bushings set in, as shown in Fig. 31, so that each side of the jig will fit one of the adjacent flanges. When the flange *a* is drilled with the side *a′* of the jig against it, and the flange *b* with the side *b′* against it, the holes in the two flanges will match however irregularly they may be located.

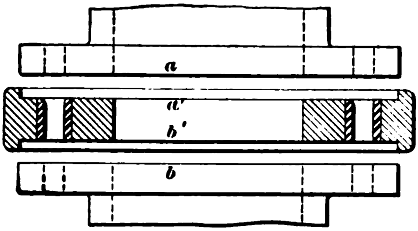


FIG. 31

60. Example of Drilling With Jig.—A jig for drilling the hub and hub plate of a locomotive wheel, in which the holes are not regularly spaced, is shown mounted on a drilling-machine table in Fig. 32. The plate *a* is supported on parallels *b* resting on the table *c*. The jig *d* has a lip *e* on each side, to fit the bores of both the plate and the wheel. The set-in bushings are shown at *g*. A single clamp *f* holds both jig and plate in place.

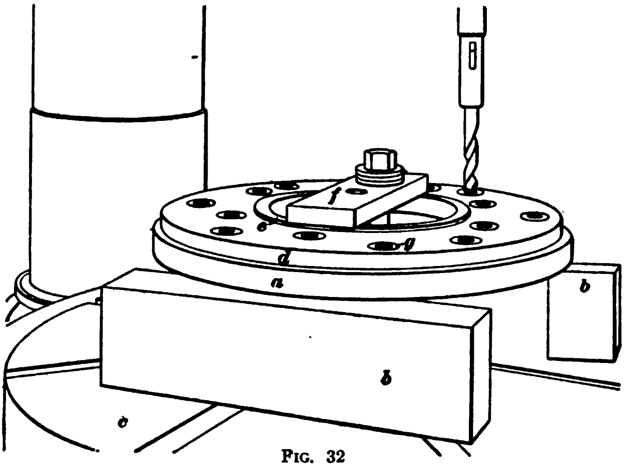
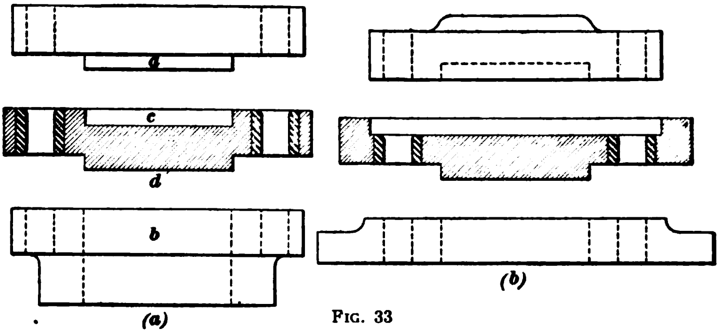


FIG. 32

61. Outside and Inside Jig.—A jig used in drilling two parts, one of which has a projection *a* that must fit into a bored hole *b* on the other, is shown in Fig. 33 (*a*). The jig is made with a counterbore *c* on one side, which will fit the projection *a*,



(*a*)

(*b*)

FIG. 33

and a projection *d* on the other side to fit the bore *b*. This same arrangement may be used when drilling parts of different sizes, as, for instance, a manhole and its cover, as shown in (*b*).

62. Jigs for Irregular Surfaces.—The jigs shown thus far are intended for circular pieces, but the principle involved may be applied to pieces of any form, with either regular or irregular surfaces. Fig. 34 shows a right-hand and left-hand jig used when drilling parts of the saddles of a vertical boring mill. One of the pieces is shown at *a*, and a number of them are piled up at *b*. A right-hand piece *c* and a left-hand piece *d* are bolted on the floor plate of a radial drill, with the jigs in place ready for drilling. All the holes in the two pieces are drilled without moving either piece. The upper surface of the saddle being uneven, several holes are required on the level *e*, and others on the level *f*. The illustration shows how the jig is formed to fit the uneven surfaces.

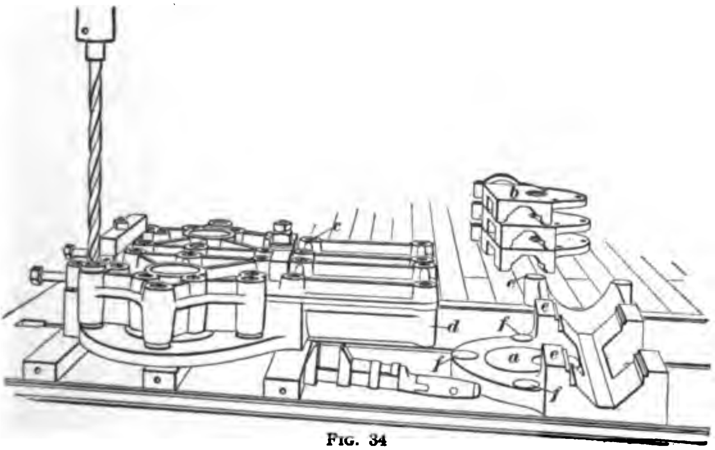
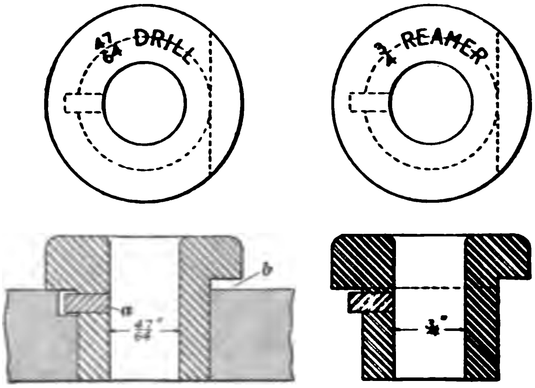


Fig. 34

63. Drill and Reamer Bushings.—Many holes drilled by the use of jigs require reaming at the same time, in which case different forms of bushings are used. The body of the jig is made of cast iron, as usual, but the bushings, instead of being forced into their seats, are made so that they may be set in with the fingers. Each is a tight sliding fit and is prevented from turning with the drill by cutting a small key seat in the jig body, as in Fig. 35 (*a*), and putting a pin *a* in the bushing so that it enters the key seat when the bushing is in place. The under side of the flange of the bushing is cut away at one point, as shown at *b*, so that a screw driver can be used to pry out the bushing when a change is to be made.

When a hole is to be drilled and reamed by the use of a jig, the drill bushing is put in the jig and a drill $\frac{1}{64}$ inch small is used to drill the hole. The drill bushing is then replaced by the full-sized reamer bushing, the speed is reduced, and the reamer is run through, which completes the hole.



(*a*) Fig. 35 (*b*)

A pair of bushings suitable for drilling and reaming a $\frac{3}{4}$-inch hole are shown in Fig. 35 (*a*) and (*b*). The drill for the hole is $\frac{47}{64}$ inch in diameter, and the reamer bushing has a $\frac{3}{4}$-inch hole through which the $\frac{3}{4}$-inch reamer passes freely. If holes are completed by drilling, the bushings are tight in their seats, and are made to the full size of the finished hole.

DRILLING AND REAMING LOCOMOTIVE CONNECTING-RODS

64. When drilling and reaming the ends of locomotive connecting-rods and similar work, a machine with two heads supported on a common cross-rail, so that the spindles may be set at any position along the cross-rail, is frequently employed.

Fig. 36 shows the table of such a machine with a connecting-rod *a* fastened upon it. The one spindle is fitted with a drill *b* to form a guide hole for the pin *f* of the annular cutter, and the other spindle is equipped with an annular cutter *c*, with two tools *e* to remove the body of the metal from the hole, the hole having previously been formed for the center pin *f*. The hole formed by the annular cutter is finished with the reamer *d*, which is of the inserted-tooth type. The holes in the reamer are made simply to reduce the weight. The piece is held on the table by two clamps *g* and *h*, the end *i* being laid flat on the surface and the end *j* resting on a parallel *k*, which is equal in thickness to the vertical distance between the two lower faces.

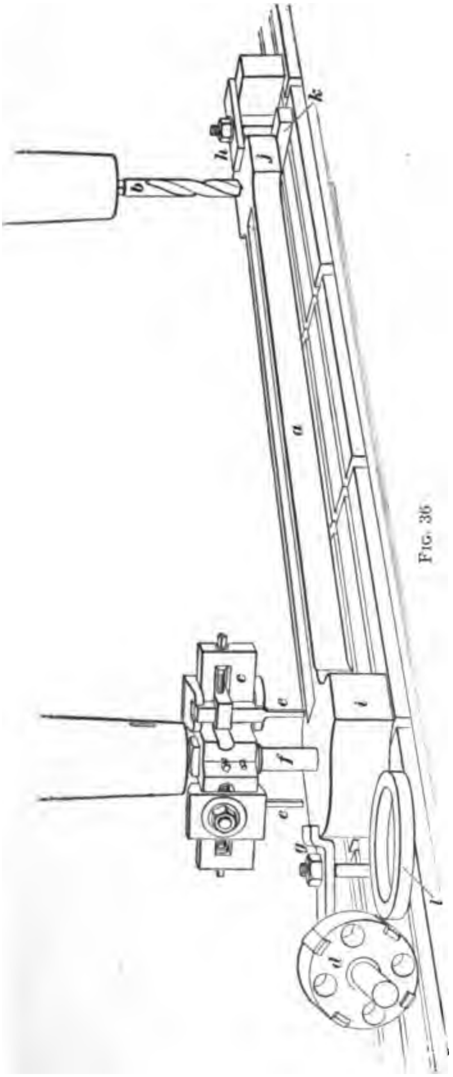


Fig. 36

65. Circular parallels *l*, Fig. 36, of different thicknesses are often used when blocking up the ends of the rod, each size of rod having its own set of parallels. The inside diameter of the parallel is greater than the diameter of the corresponding hole in the rod.

FIXTURES FOR SUPPORTING AND ROTATING WORK

66. V Supports.—A very useful device for drilling rolls is shown in Fig. 37. Two pedestals *a* of suitable height are placed on the base of the drilling machine at a sufficient distance apart to accommodate the work to be drilled. Two **V**-shaped bearings *b* are placed on the pedestals, and are so lined up that the center of a shaft lying on them will lie in the center lines of the drill spindles. The drills will, therefore, always drill radial holes in a cylinder whose shaft rests on these **V**'s. It is necessary to lay out the holes, place the shaft of the cylinder on the pedestals, and adjust the drill spindles to the right distance apart, and drill in circles about the cylinder, as indicated by the rows of holes shown, the cylinder being turned on the

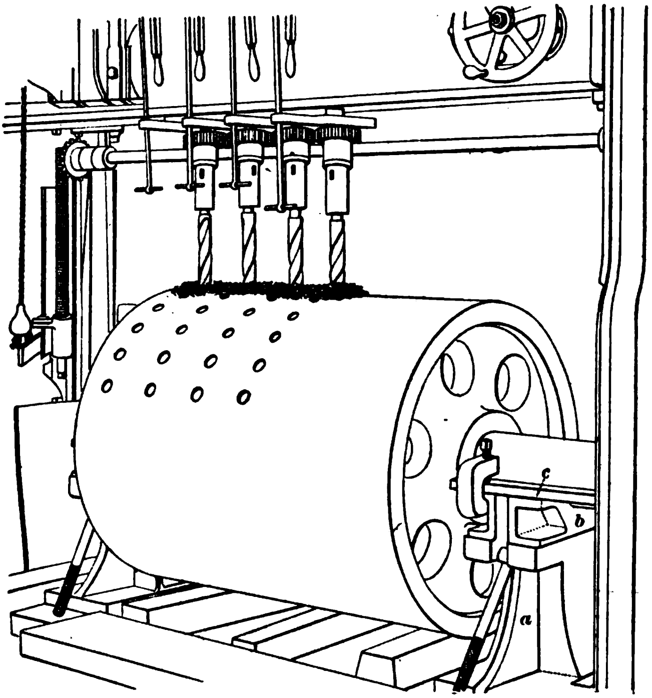


Fig. 37

V's until each successive set of holes comes under the drills. The cylinder is kept from working endwise by the bar *c*, which is set against the hub and clamped to the pedestal. The cylinder shown in this illustration is a crushing roll for anthracite. When the holes are drilled, they must be reamed before the teeth are inserted.

67. Roller Supports.—A roll set up ready for reaming in a radial drill is shown in Fig. 38. It is supported on four rollers *a*, held in two frames *d*, one at each end of the roll. The first row of holes is adjusted vertically above the axis of the roll by means of a surface gauge, with which a set of holes on opposite sides of the center are brought an equal distance from the floor. When this adjustment has been made, a pin *b* is inserted in a hole at about the height of the center line, and a block *c* is so fitted that the pin rests on it. This acts as a stop to prevent the roll from turning. When one row of holes is reamed, the pin is moved down one row

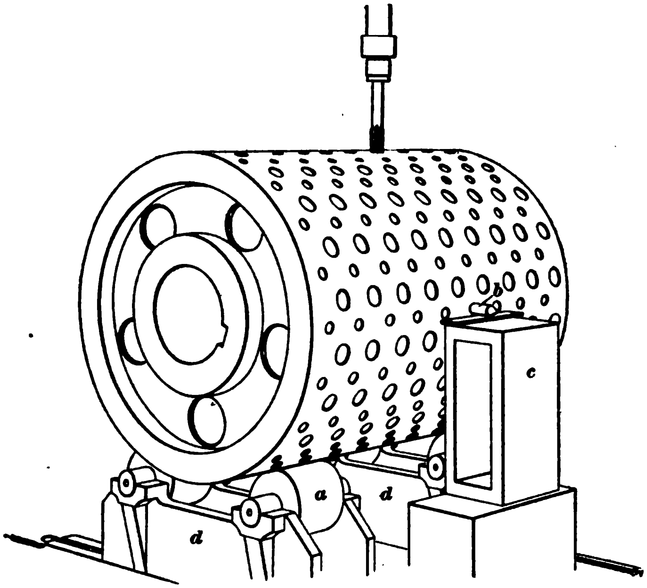


FIG. 38

and then brought up by turning the roll until it again rests on the block, thus furnishing a very simple means for adjusting each successive row.

68. Heavy Centers.—The device shown in Fig. 39 is very good for holding heavy parts with circular ends, such as pump chambers, under a radial drill. Two uprights *a* and two cones *b* provided with roller bearings, support the work, the cones entering the ends of the work, as shown. A rod *c* passing through the center of the cones and the casting keeps the uprights from spreading. The piece is set in the correct position for drilling one set of flanges, the tie-rod *c* is tightened, and all the holes in this plane are then drilled. The rod is then loosened slightly and the piece is turned until another face comes into position, when it is again tightened, and the drilling on this face is performed. This operation is repeated until all the holes are drilled. The rollers in the hub *d* reduce the friction of the bearings so that heavy pieces may be turned easily. When any regular series of spaces is required, a special index may be attached at one end, to facilitate the setting.

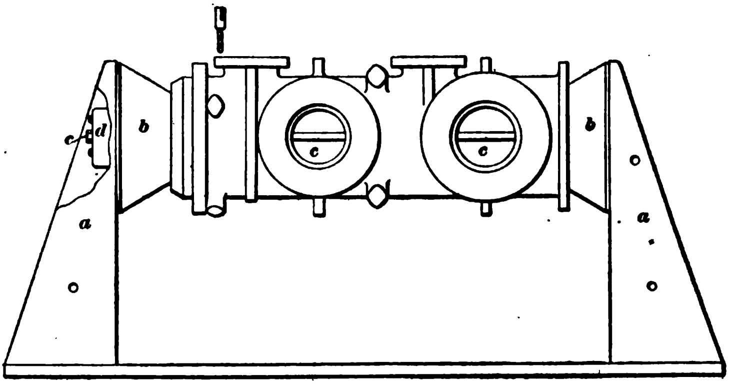


Fig. 39

69. Double Face Plate.—A double face plate to support work that has faced circular flanges with regularly spaced bolt holes is shown in Fig. 40. Two face plates *a* and *b* are supported by a bearing on each side of the bracket *c*, which may be clamped on the floor plate of a drilling machine. The flanged piece *d*, which is to be drilled and faced at *e*, *f*, and *g*, and at corresponding points opposite *e* and *f*, is attached to the face plate by three arms *h*, bolted to the plate by bolts *i*, and to the flanges by bolts *j*. The face plates are rotated to the right position for drilling, where they are held in place by the latch *k*, which enters notches in the plates. By placing notches at proper points, holes may be drilled at any angle. In the piece shown, the holes are drilled at right angles to each other, and the face plates are held in position by the notches at *k* and *l*. The plates are rotated by bars inserted in a series of holes *m*, *n*, *o*, etc. about the circumference.

70. Only one piece is shown attached to the plate *a*, Fig. 40. In doing work, ordinarily, another piece is attached to the plate *b*, thereby balancing the device so as to prevent springing of the bracket *c*, or cramping while turning to a new position. This also permits twice as many holes to be drilled without moving the face plate as when only one piece is attached, and the service of the power crane is required only one-half as often. The face plates may be made to take pieces of various sizes by moving the arms *h* to suitable positions. A series of holes *r* for the bolts *i* are provided, in the face plates shown, to accommodate pieces of different sizes. A large variety of work may be supported in this way by means of suitable arms. A key *s* under each arm, which fits into a corresponding keyway, as shown at *t*, together with the bolt *i*, locates the arm positively. When the piece is out of balance so much as to prevent it from turning, counterweights may be attached to the face plates.

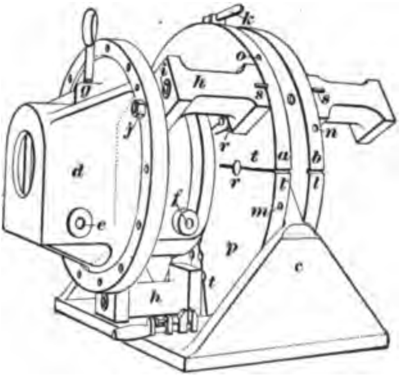


FIG. 40

71. Trunnion Supports.—A trunnion fixture for drilling duplex pump cylinders is shown in Fig. 41. The cylinders *a* and *b* are held by means of two plates *c*, which, on one side, have projections entering the ends of the cylinders, and, on the other side, trunnions *d* that rest on **V**'s on the uprights *e* of the frame of the fixture. Bolts *f* hold the plates *c* in place and form guides for the jig *g*, by means of which holes are drilled in the hubs *h* and *i*. When the fixture is in position for drilling, the trunnions are fastened by the clamps *n*.

72. The bushing *j* and the drill *k*, Fig. 41, are shown in place, ready to drill the hole. The hub *i* is supported on the lower side by a piece of pipe *l*. When both the hubs *h* and *i* are drilled, the jig *g* is moved away from the hubs in the direction of the arrow *m*, and the ends of the hubs are faced with a double-end cutter. The clamp *n* is then loosened and the cylinders are turned on the trunnions *d* to the next position to be drilled. The four holes *o* are drilled with the jig *p*, which is lying on the floor, while the four holes *q* are drilled with the jig *s* attached as shown. These cylinders have holes to be drilled on four sides, and must be set in as many positions.

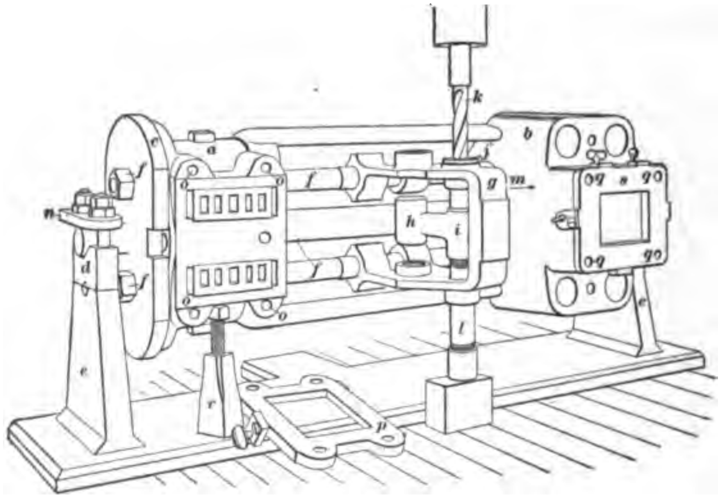


Fig. 41

When the piece is once set up for one position, it is a simple matter to move it to any of the other positions. Screw jacks *r* are used in adjusting and holding the work. The piece may be set in position by means of a square or level.

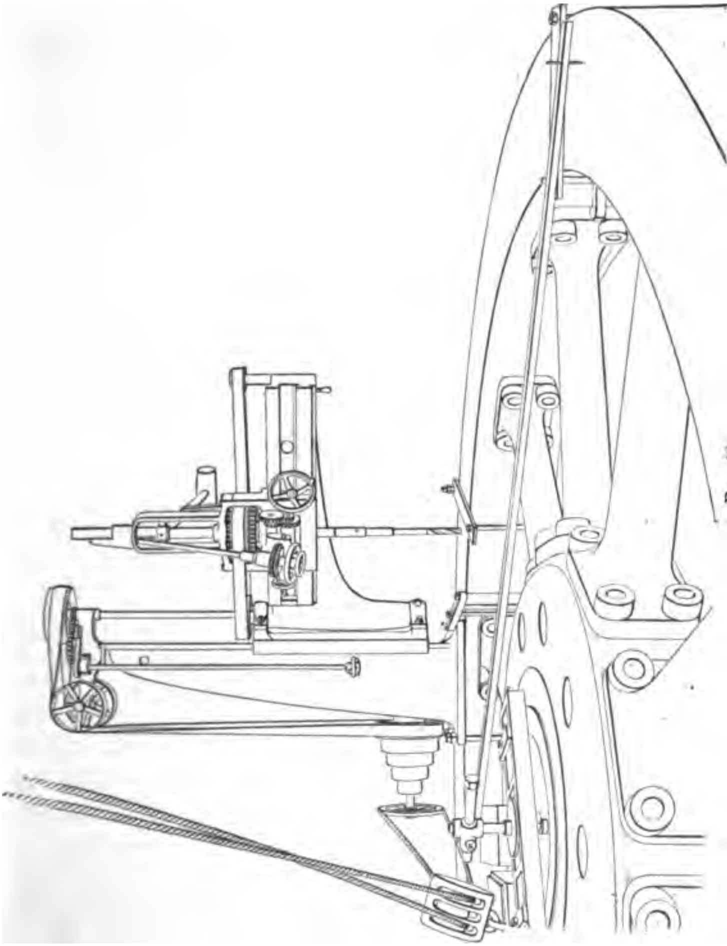


FIG. 42

73. Heavy Drilling Operation.—Parts that are too heavy to be machined in ordinary stationary machine tools are now met with quite commonly in machine shops. This has led to the use of large cast-iron floors on which the work is placed, and portable machine tools that may be carried to the floor and set up in any position to accommodate the work. Fig. 42 illustrates a case where a 135-ton flywheel was to be drilled at intervals along the rim for the purpose of joining the sections in which it was cast. The separate parts were machined and fitted together; but to make the joints, several 2-inch holes had to be drilled through 26 inches of solid metal. An ordinary radial drill was lifted from its base and set on the rim, as shown. When the holes at one joint were drilled, it was moved to the next joint and the operation was repeated, until all the joints were completed. A rope drive was used in transmitting the power to the drill. The idlers were attached at the center of the wheel, thereby making it possible to move the machine to any point on the rim without changing the length of the rope.

CUTTING SPEEDS AND FEEDS

74. It is not practicable to give rules or tables showing the cutting speeds and feeds to be used in drilling, because there are too many variable conditions to be considered. The rate of cutting will depend on the material being drilled, its degree of hardness, the stiffness of the machine, the quality of the steel of which the drills are made, and the sharpness of the drills. Also, there are some operators who prefer to use a high speed and a slow feed, whereas, others prefer to use a slow speed and a rapid feed. As a consequence, the experience and judgment of the operator must determine the speed and feed required to produce the most economical results.

75. One company manufacturing twist drills recommends an average feed of from .004 to .007 inch per revolution for drills up to and including $\frac{1}{4}$ inch in diameter, and from .007 to .015 inch per revolution for larger sizes. These feeds are for carbon-steel drills and are based on cutting speeds of 30 feet per minute for steel and wrought iron, 35 feet per minute for cast iron, and 60 feet per minute for brass. The speeds of different sizes of drills for steel, iron, and brass are shown in Table VI, at the end of this Section. If alloy-steel drills are used, the feeds may be kept the same, but the speeds may be doubled, or even trebled. The highest speeds, however, should be reached by gradual stages. It should be clearly understood that the foregoing speeds and feeds are for average conditions only. In some cases they may be exceeded, and in other cases they may have to be reduced. If the corners of the cutting lips of a drill wear away rapidly, the speed should be reduced; and if the drill chips or breaks at the cutting edges, the feed should be reduced.

76. The speeds and feeds that can be used for drills of carbon steel and alloy steel, as suggested by one manufacturer, are given in Tables VII and VIII. They were obtained by a special committee that worked for more than 2 years in testing various sizes of drills at different speeds and feeds to determine the most efficient conditions. These feeds and speeds are much higher than have been suggested heretofore, and should be taken as maximum values. They cannot be used with safety or economy for ordinary drilling machines, but are intended for high-speed ball-bearing machines of stiff and heavy construction. It may be seen that the cutting speed with high-speed drills is double that with carbon-steel drills.

77. Experiments made by the Bickford Drill Company and others show that, with drilling machines of stiff design, heavier feeds and speeds may be used than are usually employed, and that the breaking of drills has been due largely to springing of the drilling machine. It must not be inferred, however, that these experimental feeds can be used in ordinary machines, as extraordinary stiffness in the horizontal arm and vertical column is required to use them successfully. Even with such machines it is not always possible to use them in ordinary practice, and it is probable that slightly lighter feeds may be established for general use with machines of strong design.

The results of these experiments are given in Tables IX to XI, and they will suggest approximately the feeds that can safely be taken in machine tools of great stiffness. Many drills were tested to destruction in ordinary cast iron, and some tests were made in machinery steel with larger drills, but very few broke. Table IX gives the feeds used in ordinary cast iron without the least injury to the drills. Table X gives the feeds at which the drills broke, and Table XI gives the speeds at which the drills were run.

TABLE I
STANDARD STEAM, GAS, AND WATER PIPE

Sizes of Pipes Inches	Threads per Inch	Actual External Diameter Inches	Actual Internal Diameter Inches	Total Length of Thread Inches	Length of Perfect Thread Inches	Size of Hole for Tap Inches	Diameter of Thread at End of Pipe, in Inches	
							Outside	At Bottom of Thread
$\frac{1}{8}$	27	.405	.270	.41	.19	$\frac{11}{32}$	.393	.334
$\frac{1}{4}$	18	.540	.364	.62	.29	$\frac{7}{16}$	.522	.433
$\frac{3}{8}$	18	.675	.494	.63	.30	$\frac{37}{64}$	.658	.568
$\frac{1}{2}$	14	.840	.623	.83	.39	$\frac{23}{32}$	.815	.701
$\frac{3}{4}$	14	1.050	.824	.84	.40	$\frac{59}{64}$	1.025	.911
1	$11\frac{1}{2}$	1.315	1.048	1.03	.51	$1\frac{5}{32}$	1.283	1.144
$1\frac{1}{4}$	$11\frac{1}{2}$	1.660	1.380	1.06	.54	$1\frac{1}{2}$	1.627	1.488
$1\frac{1}{2}$	$11\frac{1}{2}$	1.900	1.611	1.07	.55	$1\frac{47}{64}$	1.866	1.727
2	$11\frac{1}{2}$	2.375	2.067	1.10	.58	$2\frac{13}{64}$	2.339	2.223
$2\frac{1}{2}$	8	2.875	2.468	1.64	.89	$2\frac{5}{8}$	2.820	2.620
3	8	3.500	3.067	1.70	.95	$3\frac{1}{4}$	3.441	3.241
$3\frac{1}{2}$	8	4.000	3.548	1.75	1.00	$3\frac{3}{4}$	3.938	3.738
4	8	4.500	4.026	1.80	1.05	$4\frac{1}{4}$	4.434	4.234
$4\frac{1}{2}$	8	5.000	4.508	1.85	1.10	$4\frac{3}{4}$	4.931	4.731
5	8	5.563	5.045	1.91	1.16	$5\frac{19}{64}$	5.490	5.290
6	8	6.625	6.065	2.01	1.26	$6\frac{23}{64}$	6.546	6.346
7	8	7.625	7.023	2.11	1.36	$7\frac{11}{32}$	7.540	7.340
8	8	8.625	7.982	2.21	1.46	$8\frac{11}{32}$	8.534	8.334
9	8	9.625	8.937	2.32	1.57	$9\frac{11}{32}$	9.527	9.327
10	8	10.750	10.019	2.43	1.68	$10\frac{29}{64}$	10.645	10.445

NOTE.—The taper of the threaded part is 1 in 16, or $\frac{3}{4}$ inch per foot.

TABLE II

TAP DRILLS FOR TAPS WITH V THREADS

(From Morse Twist Drill and Machine Company)

Diameter of Tap Inch	Threads per Inch	Number of Drill	Diameter of Tap Inch	Threads per Inch	Number or Diameter of Drill	Diameter of Tap Inches	Threads per Inch	Diameter of Drill	Diameter of Tap Inches	Threads per Inch	Diameter of Drill
3/32	48	50	7/32	24	20	19/32	12	31/64	1 7/32	7	1 1/64
3/32	52	50	7/32	28	17	19/32	14	1/2	1 7/32	8	1 3/64
3/32	54	49	7/32	30	16	5/8	10	31/64	1 1/4	7	1 3/64
3/32	56	49	7/32	32	15	5/8	11	1/2	1 9/32	7	1 5/64
3/32	60	48	15/64	24	16	5/8	12	33/64	1 5/16	7	1 7/64
7/64	32	50	15/64	28	12	21/32	10	33/64	1 11/32	7	1 9/64
7/64	36	49	15/64	32	10	21/32	11	17/32	1 3/8	6	1 1/8
7/64	40	47	1/4	18	17	21/32	12	35/64	1 13/32	6	1 5/32
7/64	48	44	1/4	20	14	11/16	11	9/16	1 7/16	6	1 3/16
7/64	56	43	1/4	24	9	11/16	12	37/64	1 15/32	6	1 7/32
1/8	32	44	9/32	16	:0	23/32	11	19/32	1 1/2	6	1 17/64
1/8	36	43	9/32	18	15/64	23/32	12	39/64	1 17/32	6	1 19/64
1/8	40	42	9/32	20	3	3/4	10	39/64	1 9/16	6	1 21/64
1/8	42	41	5/16	16	1	3/4	11	5/8	1 19/32	6	1 23/64
1/8	48	39	5/16	18	15/64	3/4	12	41/64	1 5/8	5	1 23/64
9/64	30	41	11/32	16	F	25/32	10	41/64	1 5/8	5½	1 25/64
9/64	32	40	11/32	18	17/64	25/32	11	21/32	1 21/32	5	1 25/64
9/64	36	37	3/8	14	J	25/32	12	43/64	1 21/32	5½	1 27/64
9/64	40	34	3/8	16	L	13/16	10	43/64	1 11/16	5	1 27/64
5/32	30	33	3/8	18	19/64	27/32	10	45/64	1 11/16	5½	1 29/64
5/32	32	32	13/32	14	N	7/8	9	23/32	1 23/32	5	1 29/64
5/32	36	31	13/32	16	P	7/8	10	47/64	1 23/32	5½	1 31/64
5/32	40	30	13/32	18	21/64	29/32	9	3/4	1 3/4	5	1 31/64
11/64	32	30	7/16	14	R	15/16	9	25/32	1 25/32	5	1 33/64
11/64	36	29	7/16	16	S	31/32	9	13/16	1 13/16	5	1 35/64
11/64	40	28	15/32	14	3/8	1	8	53/64	1 27/32	5	1 37/64
3/16	24	29	15/32	16	W	1 1/32	8	55/64	1 7/8	4½	1 37/64
3/16	28	28	1/2	12	25/64	1 1/16	8	57/64	1 7/8	5	1 39/64
3/16	30	27	1/2	13	X	1 3/32	8	59/64	1 29/32	4½	1 39/64
3/16	32	26	1/2	14	13/32	1 1/8	7	59/64	1 29/32	5	1 41/64
3/16	36	24	17/32	12	27/64	1 1/8.	8	61/64	1 15/16	4½	1 41/64
13/64	24	26	17/32	13	27/64	1 5/32	7	61/64	1 15/16	5	1 43/64
13/64	28	22	17/32	14	7/16	1 5/32	8	63/64	1 31/32	4½	1 43/64
13/64	32	20	9/16	12	29/64	1 3/16	7	63/64	1 31/32	5	1 45/64
13/64	36	18	9/16	14	15/32	1 3/16	8	1 1/64	2	4½	1 45/64

TABLE III

TAP DRILLS FOR MACHINE-SCREW TAPS

(*From Morse Twist Drill and Machine Company*)

Size of Tap	Number of Drill	Size of Tap	Number of Drill	Size of Tap	Number or Letter of Drill
2×48	50	9×30	27	17×16	6
2×56	49	9×32	25	17×18	2
2×64	48	10×24	25	17×20	2
3×40	47	10×30	22	18×16	2
3×48	45	10×32	21	18×18	1
3×56	44	11×24	21	18×20	B
4×32	43	11×28	17	19×16	A
4×36	42	11×30	17	19×18	C
4×40	41	12×20	19	19×20	D
5×30	40	12×22	17	20×16	D
5×32	40	12×24	17	20×18	F
5×36	38	12×28	15	20×20	H
5×40	37	13×20	15	22×16	J
6×30	35	13×22	15	22×18	L
6×32	35	13×24	13	24×14	M
6×36	33	14×20	13	24×16	N
6×40	32	14×22	11	24×18	O
7×28	32	14×24	9	26×14	O
7×30	31	15×18	10	26×16	P
7×32	30	15×20	8	28×14	R
8×24	30	15×22	6	28×16	S
8×30	30	15×24	5	30×14	U
8×32	29	16×16	7	30×16	V
9×24	29	16×18	6		
9×28	28	16×20	5		

NOTE.—For steel work use a drill one or two sizes larger than listed.

TABLE IV

TAP DRILLS FOR TAPS WITH UNITED STATES STANDARD THREADS

(*From Morse Twist Drill and Machine Company*)

Diameter of Tap Inch	Threads per Inch	Diameter or Letter of Drill	Diameter of Tap Inches	Threads per Inch	Diameter of Drill	Diameter of Tap Inches	Threads per Inch	Diameter of Drill	Diameter of Tap Inches	Threads per Inch	Diameter of Drill
1/4	20	3/16 in.	11/16	11	37/64	1 1/4	7	1 5/64	2 1/8	4 1/2	1 27/32
5/16	18	C	3/4	10	5/8	1 3/8	6	1 11/64	2 1/4	4 1/2	1 31/32
3/8	16	N	13/16	10	11/16	1 1/2	6	1 19/64	2 3/8	4	2 1/16
7/16	14	S	7/8	9	47/64	1 5/8	5 1/2	1 25/64	2 1/2	4	2 3/16
1/2	13	13/32 in.	15/16	9	51/64	1 3/4	5	1 1/2			
9/16	12	29/64 in.	1	8	27/32	1 7/8	5	1 5/8			
5/8	11	33/64 in.	1 1/8	7	61/64	2	4 1/2	1 23/32			

TABLE V

LUBRICANTS FOR DRILLING, REAMING, AND TAPPING

(*From Morse Twist Drill and Machine Company*)

Material	Drilling	Reaming	Tapping
Tool Steel	Oil	Lard oil	Oil
Soft steel	Oil or soda water	Lard oil	Oil
Wrought iron	Oil or soda water	Lard oil	Oil
Cast iron	Dry	Dry	Oil
Brass	Dry	Dry	Oil
Copper	Oil	Mixture	Oil
Babbitt	Dry	Dry or kerosene	Oil
Glass	Turpentine		

TABLE VI

SPEEDS AND FEEDS FOR CARBON-STEEL DRILLS

(*From Cleveland Twist Drill Company*)

Diameter of Drill Inch	Materials			Diameter of Drill Inches	Materials		
	Soft Steel	Iron	Brass		Soft Steel	Iron	Brass
	Revolutions per Minute				Revolutions per Minute		
$\frac{1}{16}$	1,824	2,128	3,648	$1\frac{1}{16}$	108	125	215
$\frac{1}{8}$	912	1,064	1,824	$1\frac{1}{8}$	102	118	203
$\frac{3}{16}$	608	710	1,216	$1\frac{3}{16}$	96	112	192
$\frac{1}{4}$	456	532	912	$1\frac{1}{4}$	91	106	182
$\frac{5}{16}$	365	425	730	$1\frac{5}{16}$	87	101	174
$\frac{3}{8}$	304	355	608	$1\frac{3}{8}$	83	97	165
$\frac{7}{16}$	260	304	520	$1\frac{7}{16}$	80	93	159
$\frac{1}{2}$	228	266	456	$1\frac{1}{2}$	76	89	152
$\frac{9}{16}$	203	236	405	$1\frac{9}{16}$	73	85	145
$\frac{5}{8}$	182	213	365	$1\frac{5}{8}$	70	82	140
$\frac{11}{16}$	166	194	332	$1\frac{11}{16}$	68	79	135
$\frac{3}{4}$	152	177	304	$1\frac{3}{4}$	65	76	130
$\frac{13}{16}$	140	164	280	$1\frac{13}{16}$	63	73	125
$\frac{7}{8}$	130	152	260	$1\frac{7}{8}$	60	71	122
$\frac{15}{16}$	122	142	243	$1\frac{15}{16}$	59	69	118
1	114	133	228	2	57	67	114

TABLE VII

FEEDS AND SPEEDS FOR CARBON-STEEL DRILLS

(Copyrighted by Henry & Wright Manufacturing Company and used by permission)

Diameter of Drill Inches	Feed per Revolution Inch	Materials to be Drilled							
		Brass or Bronze	Annealed Cast Iron	Hard Cast Iron	Mild Steel	Drop Forgings	Malleable Iron	Tool Steel	Steel Castings
		Cutting Speed, in Feet per Minute							
		150	85	40	60	30	45	30	20
		Revolutions per Minute of Drill							
$\frac{1}{16}$	.003		5,185	2,440	3,660	1,830	2,745	1,830	1,220
$\frac{1}{8}$	.004	4,575	2,593	1,220	1,830	915	1,375	915	610
$\frac{3}{16}$	.005	3,050	1,728	813	1,220	610	915	610	407
$\frac{1}{4}$	.006	2,287	1,296	610	915	458	636	458	305
$\frac{5}{16}$	.007	1,830	1,037	488	732	366	569	366	245
$\frac{3}{8}$	.008	1,525	864	407	610	305	458	305	203
$\frac{7}{16}$	.009	1,307	741	349	523	261	392	261	174
$\frac{1}{2}$	.010	1,143	648	305	458	229	343	229	153
$\frac{5}{8}$	.011	915	519	244	366	183	275	183	122
$\frac{3}{4}$	.012	762	432	204	305	153	212	153	102
$\frac{7}{8}$	.013	654	371	175	262	131	196	131	87
1	.014	571	323	153	229	115	172	115	77
$1\frac{1}{4}$	.016	458	260	122	183	92	138	92	61
$1\frac{1}{2}$	.016	381	216	102	153	77	106	77	51
$1\frac{3}{4}$	.016	327	186	88	131	66	98	66	44
2	.016	286	162	87	115	58	86	58	39

TABLE VIII

FEEDS AND SPEEDS FOR HIGH-SPEED STEEL DRILLS

(Copyrighted by Henry & Wright Manufacturing Company and used by permission)

Diameter of Drill Inches	Feed per Revolution Inch	Materials to be Drilled							
		Brass or Bronze	Annealed Cast Iron	Hard Cast Iron	Mild Steel	Drop Forgings	Malleable Iron	Tool Steel	Steel Castings
		Cutting Speed, in Feet per Minute							
		300	170	80	120	60	90	60	40
		Revolutions per Minute of Drill							
$\frac{1}{16}$	.003			4,880		3,660		3,660	2,440
$\frac{1}{8}$	.004		5,185	2,440	3,660	1,830	2,745	1,830	1,220
$\frac{3}{16}$	.005		3,456	1,626	2,440	1,210	1,830	1,220	807
$\frac{1}{4}$	.006	4,575	2,593	1,220	1,830	915	1,375	915	610
$\frac{5}{16}$	.007	3,660	2,074	976	1,464	732	1,138	732	490
$\frac{3}{8}$	.008	3,050	1,728	813	1,220	610	915	610	407
$\frac{7}{16}$	.009	2,614	1,482	698	1,046	522	784	522	348
$\frac{1}{2}$	.010	2,287	1,296	610	915	458	636	458	305
$\frac{5}{8}$	.011	1,830	1,037	488	732	366	569	366	245
$\frac{3}{4}$	.012	1,525	864	407	610	305	458	305	203
$\frac{7}{8}$	.013	1,307	741	349	523	261	392	261	174
1	.014	1,143	648	305	458	229	349	229	153
$1\frac{1}{4}$	.016	915	519	244	366	183	275	183	122
$1\frac{1}{2}$	.016	762	432	204	305	153	212	153	102
$1\frac{3}{4}$	.016	654	371	175	262	131	196	131	87
2	.016	571	323	153	229	115	172	115	77

TABLE IX

FEEDS USED IN ORDINARY CAST IRON WITHOUT INJURY

Diameter of Drill Inches	Feed per Revolution Inch
1/4 to 1/2	.025
1/2 to 1	.035
1 to 1 1/2	.047

TABLE X

FEEDS AT WHICH DRILLS BROKE IN ORDINARY CAST IRON

Diameter of Drill Inch	Feed per Revolution at Which Drill Broke Inch	Diameter of Drill Inch	Feed per Revolution at Which Drill Broke Inch
1/16	.007	3/16	.035
3/32	.010	1/4	.047
1/8	.014	5/16	.064
5/32	.020		

TABLE XI

SPEEDS AT WHICH DRILLS WERE RUN

Diameter of Drill Inches	Revolutions per Minute	Cutting Speed Feet per Minute	Diameter of Drill Inches	Revolutions per Minute	Cutting Speed Feet per Minute
1/2	267	35	1 3/4	61	28
5/8	222	36	2	51	26
3/4	184	36	2 1/4	42	25
7/8	153	35	2 1/2	35	23
1	128	33	2 3/4	29	21
1 1/8	106	31	3	24	19
1 1/4	88	29	3 1/4	20	17
1 1/2	73	28	3 1/2	17	15

LATHE WORK

(PART 1)

LATHES AND LATHE ATTACHMENTS

ENGINE LATHE

PURPOSE AND CONSTRUCTION

1. A **lathe** is a machine used ordinarily for turning cylindrical, conical, and flat surfaces, although it may also be used for boring, that is, producing cylindrical or conical holes. The work to be turned or bored is held between centers, in a chuck, or on a face plate; or it may be secured to the carriage or the bed of the lathe. The cutting is done by one or more tools held in the tool post or holder, when the lathe is used for turning. When the lathe is used for drilling, the tool is held in one of the spindles; when it is used for boring, the tool is held in a bar between the centers. By the use of various attachments the lathe may be employed for such operations as tapping, reaming, forming, and threading.

2. Nature of Engine Lathe.—Probably a greater variety of shop work is done on the lathe than on any other machine. For this reason, lathes are divided into different sizes and classes, each of which is designed to operate on a particular class of work. The chief among these, and the one with which the workman first becomes familiar, is the *engine lathe;* and as it includes all the main features of lathes used for turning metal, it

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will be considered first. If its construction and operation are thoroughly understood, the action of any other class of lathe will easily be mastered. The three main features of the engine lathe are that it is driven by some other power than foot-power, the cutting tool is moved by some form of feed-mechanism, and a lead screw is used for cutting screw threads.

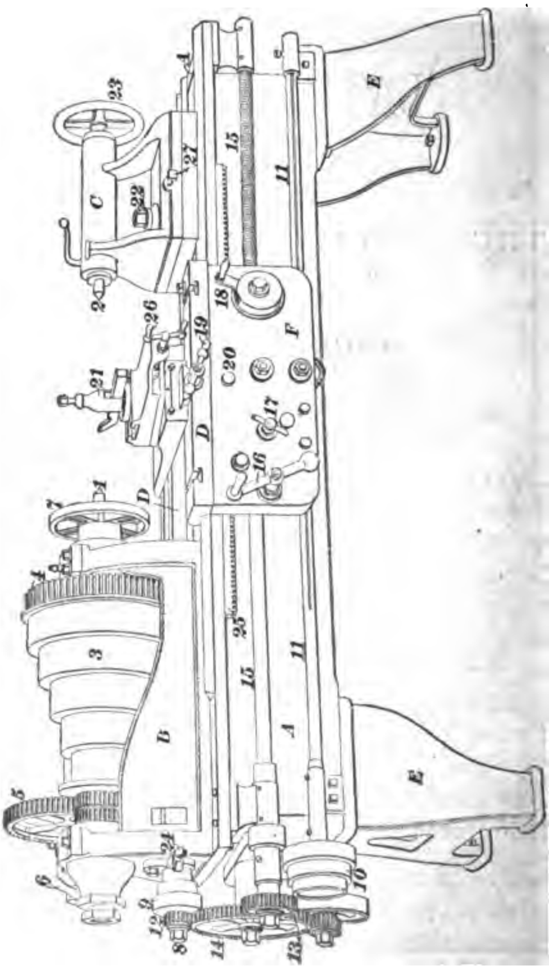


FIG. 1

3. **Main Parts of Lathe.**—An engine lathe is shown in Fig. 1. The bed *A* carries on its top the fixed headstock *B*, the movable tailstock *C*, and the saddle *D*, the whole being supported by the legs *E*. The saddle has an apron *F* attached at the front, and carries the cutting tool in a holder on its top. The saddle and the apron may be moved lengthwise along the bed by gearing at the back of the apron. The work to be turned is held between the live center *1* and the dead center *2* or in a chuck on the live spindle. A belt on the cone pulley *3* drives the gear *4*, and thus turns the live spindle in which the live center *1* is fixed. The work is thus caused to rotate. If the back gear *5* is thrown into action by pulling the handle *6* forwards, and disconnecting the spindle gear *4* from the cone, the work is rotated more slowly, but a heavier cut may be taken. If desired, work may be fastened to a larger face plate used in place of the face plate *7*; this larger face plate also rotates with the spindle.

4. At the back end of the headstock, Fig. 1, there is a stud *8* on which is a cone pulley *9* that may be connected by belt to a similar cone *10* on the feed-rod *11*, thus turning the feed-rod. The gears *12*, *13*, and *14* are used to drive the lead screw *15*, which moves the carriage when threads are being cut on the lathe. The carriage may be moved endwise by hand by turning the handle *16*. The knob *17* is turned when the carriage is to be moved by the feed-rod, and the handle *18* if the lead screw is to be used. The cross-slide carrying the tool may be moved by hand by turning the handle *19*, or by power by turning the knob *20*. The tool is clamped in the tool post *21*, which is held in a **T** slot in the cross-slide. The remaining parts are as follows: *22*, a nut for clamping the tailstock to the bed *A*; *23*, a hand wheel for adjusting the tailstock spindle and the dead center; *24*, a lever for reversing the direction of feed-motion; ~~*25*, a feed-rack~~ securely fastened to the lathe bed; *26*, a handle for operating the compound-rest cross-feed; *27*, an adjusting screw for setting over the tailstock spindle, and brought into use when the tailstock is set over in order to turn a taper.

LATHE DETAILS

5. Lathe Carriage.—The lathe carriage is composed of two parts, namely, the saddle and the apron. The saddle *D*, Fig. 1, is fitted and gibbed to the top of the lathe bed, carries the cross-slide and the tool, and receives all the thrust exerted in cutting the work. The apron *F* is secured to the saddle by screws. It hangs in front of the bed, and contains the gearing through which the feed-motion is transmitted from the feed-rod *11* to the feed-rack *25*. It also carries the split nut that engages the lead screw when cutting threads.

6. Feed-Motion.—To operate the power feed, or cause the carriage to move automatically along the lathe bed, the knob *17*, Fig. 1, is turned, thus operating a friction clutch inside the apron. This operation throws in the feed, and power is then transmitted from the spindle to the stud *8*, from the stud cone *9* to the feed-rod cone *10* by means of a belt, and so along the rod to the carriage. Each of the feed-cones *9* and *10* has three steps, and by shifting the belt three different speeds of the feed-rod *11* may be obtained. In some lathes the feed-rod is driven by gearing, thus enabling heavier feeds to be used; but there is always danger of employing a feed so heavy as to damage the gears, whereas, if a belt is used, it will slip when the feed becomes excessive, and will thus prevent damage. The direction of the feed-motion may be changed by introducing another gear into the series of gears either in the apron or on the headstock.

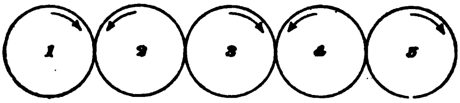


FIG. 2

7. The reversal of motion by using an extra gear may be illustrated clearly by Fig. 2, which shows a series of gears, frequently called a gear train, or train of gears. If the gear *1* turns in the direction indicated by the arrow marked on it, gears *3* and *5* will also turn in this same direction, but gears *2* and *4* will turn in the opposite direction. In other words, if the number of gears in a train is even, the first and last gears will revolve in opposite directions; but if the number of gears is odd, the first and last gears will revolve in the same direction.

8. An end view of a headstock and of the gears by which the direction of the feed-motion is controlled is shown in Fig. 3, and Fig. 4 is a detailed end view of the same headstock. The gear *1* is keyed to the spindle and the gear *3* is keyed to the stud or change-gear spindle *6*. An arm pivoted on the stud *6* carries the idlers *2* and *4*. When the handle *5* is up, motion is transmitted from the gear on the headstock spindle, through the gear *2* to the gear *3*. Then, as there are three gears in the train, the first and last gears have the same direction of rotation.

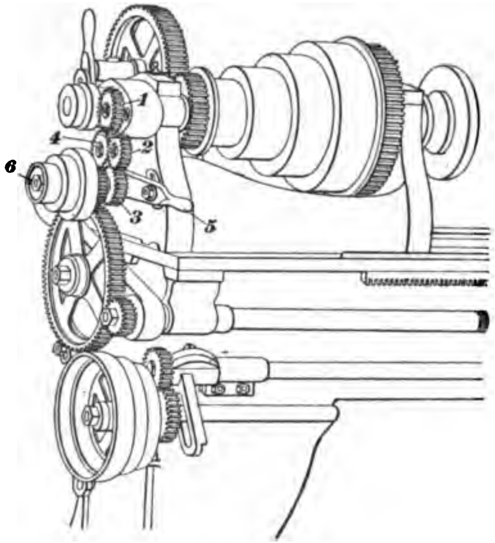


FIG. 3

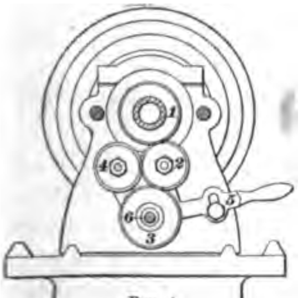


FIG. 4

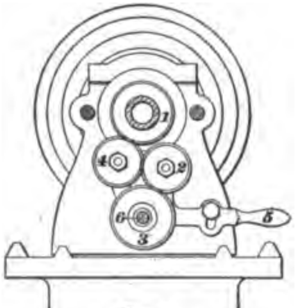


FIG. 5

When the handle *5* is pushed down, as in Fig. 5, the idler *2* is moved away from the gear *1*, and the gear *4*, which was before revolving idly, is brought against the gear *1*. Motion is then transmitted through the gears from *1* to *4*, from *4* to *2*, and from *2* to *3*. In this position there are four gears in the train and the motions of the first and last gears are in opposite directions. In Fig. 1 this same reversing mechanism is used, but the gearing is placed inside the frame of the headstock. The various speeds of the lathe are controlled by running the belt on different steps of the driving cone *3*, and by the use of the back gears.

9. Back Gears.—A horizontal section through the headstock of a lathe is shown in Fig. 6, and illustrates the action of the back gears. The back gears *b* and *c* are fixed to a hollow sleeve, or quill, that turns on a shaft held in bearings in the brackets at the back of the headstock. This shaft is eccentric; that is, its center line is not in line with the centers of the end bearings. Thus, when the handle *e* is raised and pushed backwards, the eccentric shaft is turned partly in its bearings, and the quill with the back gears *b* and *c* is moved away from the spindle. This movement throws the back gears out of mesh with the gears *a* and *d*, and thus puts the back gears out of action. A reverse

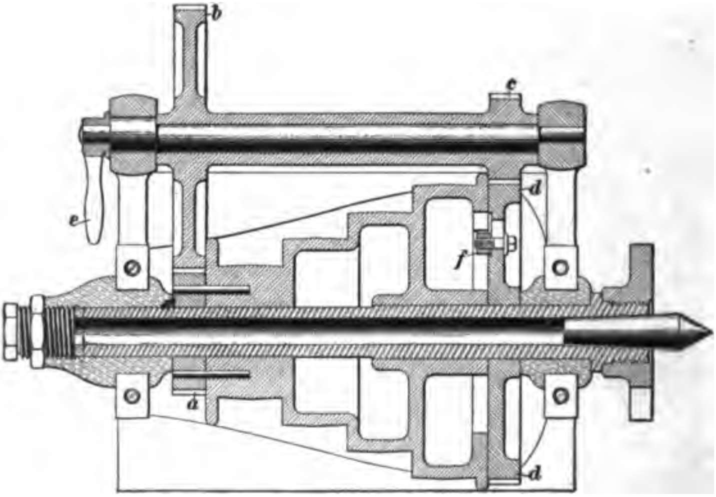


FIG. 6

movement of the handle *e* throws the back gears into action again.

10. The small gear *a*, Fig. 6, is fastened to the small end of the cone, which is loose on the spindle. The spindle gear *d*, however, is firmly keyed to the spindle, and has a radial slot for a bolt that carries a block *f* at its inner end. If the spindle is to turn at the same speed as the cone, the back gears are thrown out of action, and the block *f* is then moved outwards until it enters a slot cut in the larger end of the cone, thus locking the gear *d* to the cone, and forcing them to turn together. If the back gears are to be used, the block *f* is drawn out of the slot in the cone, so as to disengage the cone from the gear *d*. Then the handle *e* is drawn forwards, bringing the back gears *b*

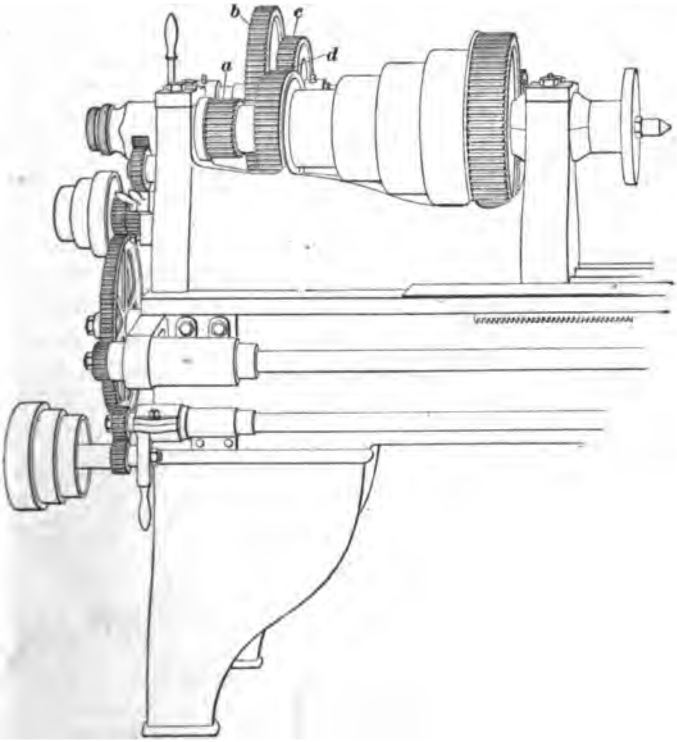


FIG. 7

and *c* into mesh with the cone and spindle gears *a* and *d*. The cone then turns the gear *a*, which drives the gear *b*, and therefore also the pinion *c* more slowly. The pinion *c* drives the gear *d* at a still slower speed, so that the effect of using the back gearing is to turn the spindle much more slowly than the cone pulley, and make it possible to take a heavier cut.

11. **Double Back Gears.**—When a greater change of speed is desired than can be obtained with the ordinary set of back gears, a second combination of gears of different ratios is introduced whereby the speed may be reduced still more. When this combination is used, the lathe is said to be double back-geared. The headstock of a lathe with double back gearing is shown in Fig. 7. The gears *b* and *c* are pinned together, and are free to slide on a feather on the back-gear shaft, so that when moved to one position, the gear *b* meshes with the gear *a* on the cone spindle, giving one rate of speed. When the gears *b* and *c* are moved to the other end of their seat, the gear *c* meshes with the gear *d*. The gears *c* and *d*, being of different diameters from the gears *b* and *a*, give a different rate of speed. The slower speed is obtained when the gears *a* and *b* are in mesh. When the gears *c* and *d* are engaged, the back gear *b* is opposite the space left between the spindle gears *a* and *d*.

12. **Triple Back Gears.**—On the larger and stronger lathes, a third set of back gears is used, and the lathes are then said to be triple-geared. Fig. 8 illustrates a lathe of this type. The first portion of the gearing is similar to that already described, but the triple gearing is obtained by means of an internal gear *a* attached to the face plate *b*, which is operated by a pinion on the shaft *d*, thus producing a very slow speed.

13. **Tailstock.**—The small engine lathe shown in Fig. 1 has the tailstock secured to the bed by a clamp bolt *22*, and it can be moved by loosening this bolt and sliding the tailstock to the desired position by hand. The weight of the tailstock of a large lathe makes this difficult or impossible, and some special method is necessary. The lathe shown in Fig. 8 has an arm *f*

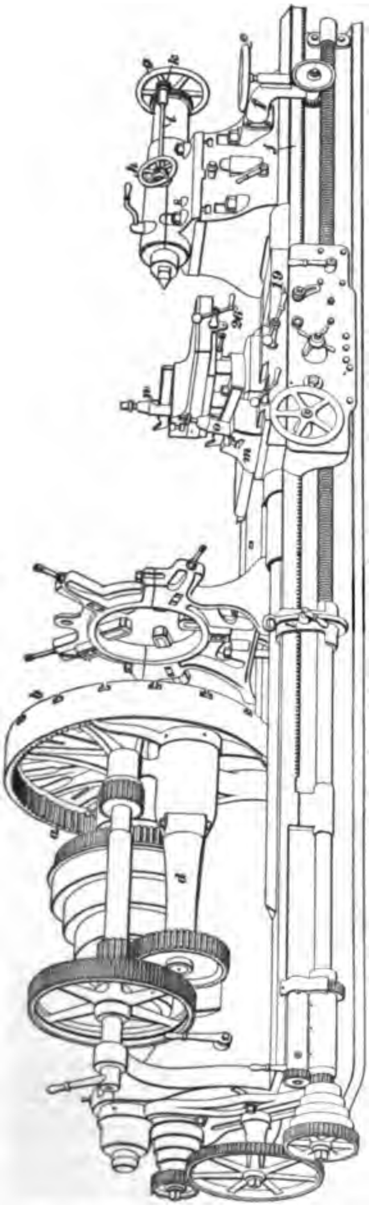


FIG. 8

attached to the tailstock and provided with a hand wheel *e* that operates the gearing arranged to engage with the rack *j*. By this device the tailstock can easily be moved by hand. In some cases, arrangement is made for connecting the traverse mechanism with the lead screw so that the tailstock may be moved by power. The lathe shown in Fig. 1 has the tailstock spindle moved in or out by means of the hand wheel *23*; but in the lathe shown in Fig. 8, the tailstock becomes of such extreme length that it is not always convenient to operate the spindle by the hand wheel *g*, and the auxiliary hand wheel *h*, the shaft *i*, and the gearing at *k* are provided, thus enabling the operator to control the spindle while he is close to the center.

14. Lead-Screw Supports.—In the case of a small lathe, as shown in Fig. 1, the lead screw and feed-rod, *15* and *11*, are simply supported at the ends and in the apron. In the case of long or heavy lathes, additional supports, as shown at *l*, Fig. 8, become necessary.

Sometimes several of these additional supports are arranged along the lathe.

15. **Large Diameter Tool Rest.**—In most lathes, the tool is secured in the ordinary tool post of the form shown at *21*, Fig. 1, and at *n*, Fig. 8; but in large lathes it is sometimes necessary to turn work that cannot be swung over the carriage. In such a case, the large diameter rest illustrated in Fig. 8 is used. It consists of an auxiliary slide *m* placed at the front end of the carriage, and the tool post *o*. Such a tool post is located considerably below the line of the lathe centers, and in order to obtain the proper cutting angles for the ordinary tools, the top slide on which the bottom of the tool rests is inclined at such an angle that a line drawn along the bottom of the tool would pass approximately through a line joining the centers on the lathe.

16. **Swing of Lathe.**—In the United States, the size of a lathe is denoted by its swing, which is the diameter of the largest piece that can be swung over the V's. A lathe that will just turn a 24-inch pulley is a *24-inch lathe*, and is said to have a *24-inch swing*. In Great Britain, the swing of a lathe is the radius of the largest piece that can be turned in it; hence, a lathe with a 24-inch swing could turn a piece 48 inches in diameter.

17. **Steady Rest.**—The attachment secured to the bed between the carriage and the face plate in Fig. 8 is a movable and adjustable work support called a *steady rest*. The lower part is held to the bed by an anchor that engages the bed under the inside pair of V's. One leg of the steady rest has a V cut in it to hold its jaws square with the axis of the centers; the other leg is flat, and rests on the top of the back V. The top of the rest hinges on the lower part at the back, and is provided with a clamp bolt at the front to hold the two parts rigidly together. Three or more adjustable jaws held in slots by clamp bolts and adjusting screws keep the work in line with the lathe centers. The steady rest is used at any required point in the length of a shaft held between centers, or to support

a piece projecting some distance from the face plate while it is being turned or bored.

18. **Live Spindle.**—The driving cone *3*, Fig. 1, is secured on and drives the live spindle of the lathe. This spindle is shown in section in Fig. 6. The spindle is bored tapering at the front end to take the tapered live center. A hole is usually made the rest of the way through the spindle, so that long work can be passed through it, and held in the chuck, and also to permit a rod to be introduced to drive out the center. The outer end or nose of the spindle is threaded a part of its length, and the rest is left plain or tapered, the better to support and steady the chuck or face plate.

19. **Thrust Bearing.**—The box at the back end of the spindle is rather long, and contains the thrust bearing, as shown in Fig. 6, to prevent end motion of the spindle when boring or doing other chuck or face-plate work. The thrust bearing is usually a hollow screw, having a head by which it is turned, and a jam nut for locking it when it is adjusted. A hardened and ground washer, or else a fiber washer is placed between the spindle and the screw to reduce both friction and wear.

20. **Details of Tailstock.**—The lathe tailstock is an attachment adjustable lengthwise along the bed, and used to support work while turning. It is used also to hold tools, such as drills and reamers, and to feed them into the work. It consists of a base *a*, Fig. 9, fitting the **V**'s of the lathe, with a cross-slide *b* on its top for the sidewise adjustment of the centers. The slide is prevented from moving endwise on the base by a tongue and groove *c* in the joint. The base is secured to the bed by clamp bolts *d* extending through the anchors *e*. The top, carrying the dead spindle *f* and the dead center *g*, is adjustable sidewise so that cylindrical and tapering work can be turned.

21. The sidewise setting of the tailstock, Fig. 9, is made by an adjusting screw *h* on each side of the tailstock. These screws pass through holes in the lower part and enter tapped holes in

corresponding lugs in the other part. By loosening one screw and tightening the other, any required sidewise adjustment is made, during which operation the clamp bolts should be slacked off. The tailstock is bored for the dead spindle *f*, and the back end of the bore is tapped and closed by screwing in the butt *i*. Passing through the butt is the left-hand adjusting screw *j* operated by the hand wheel *k*. The dead center *g* enters the taper in the dead spindle and is made to extend so far back in the spindle that it will be forced out of the taper when the dead

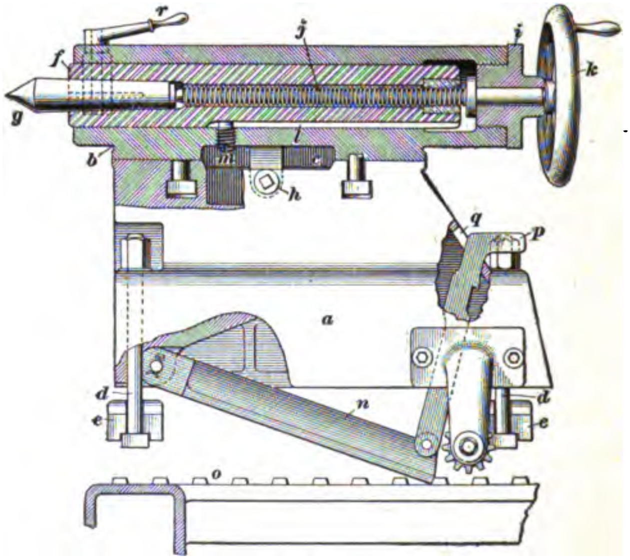


Fig. 9

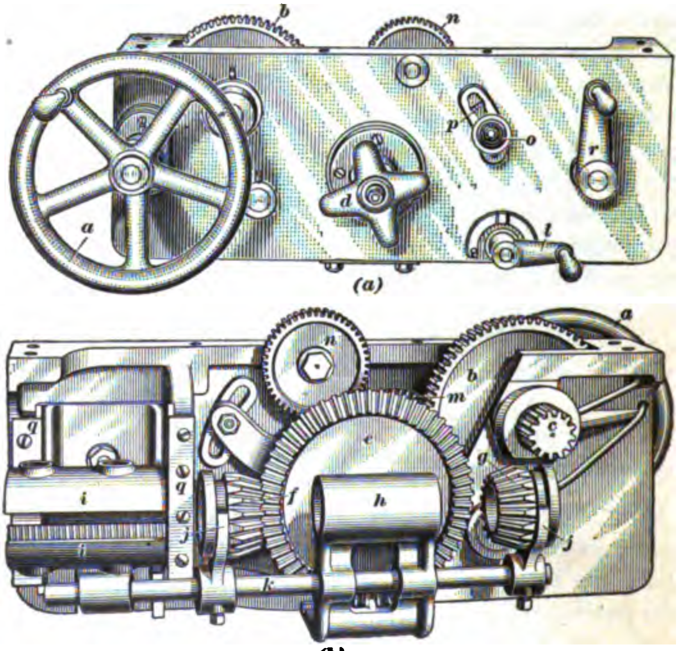
spindle is run back nearly to the collar on the feed-screw. In the lower side of the spindle is cut a keyway *l* in which fits a setscrew *m* that is flattened on two sides. This forms a key that prevents the spindle from turning, but allows it to move endwise.

22. Tailstock Thrust.—If the tailstock is to carry great weights, or must stand the stresses imposed by high-speed tools, it may be prevented from moving back by the arrangement shown in Fig. 9. A pawl *n* is secured to the under side of the tailstock, and the free end of it is allowed to fall into a rack *o* in the bed. The pawl is raised when not in use, and held out of the rack by the handle *p*, which hooks over the end of the slot *q* in the base. The handle *r* is a clamping lever that is used to lock the dead spindle in position after it has been properly adjusted. A light tailstock may easily be pushed along the **V**'s by hand; but the heavy ones require some form of moving gear.

23. Details of Apron.—There are two distinct types of lathe aprons. In one type the feed-mechanism is operated by a feed-rod, a lead screw is used for cutting threads, and the reversing gears are in the headstock. In the other, the lead screw alone operates the feed-mechanism, and gives motion to the carriage when cutting threads, and the reversing mechanism is in the apron. Front and back views of an apron operated by a lead screw and no feed-rod are shown in Fig. 10 (*a*) and (*b*). The carriage is moved endwise by hand by turning the hand wheel *a*, which is fastened to a short shaft that passes through the front plate of the apron, and carries a pinion that meshes with the gear *b*. The gear *b* is fastened on the same shaft as the pinion *c*, and the latter meshes with a rack on the lathe bed; hence, when the hand wheel *a* is turned, the pinion *c* is rotated, and the carriage is moved along the bed.

24. The automatic feed of the apron shown in Fig. 10 is thrown in by turning the knob *d*, which tightens a clutch behind the bevel gear *e*. The lead screw passes through the bevel gears *f* and *g*, the sleeve *h*, and the split nut *i*, and has a keyway cut along its full length. Each of the bevel gears *f* and *g* has a key that fits in the lead screw, so that it must turn with the screw, and yet may move endwise when the carriage moves. These bevel gears have grooved collars in which fit the forks *j* fastened to the rod *k*. By turning the handle *l* at the front of the apron, the rod *k* is moved endwise, and one of the bevel gears *f* and *g* is brought into mesh with the gear *e*. As the small bevel gears are on opposite sides of the large bevel gear *e*, and turn in the same direction, the gear *f* will rotate the gear *e* in one direction, and the gear *g* will turn it in the opposite direction. The automatic feed is thus reversed by moving the handle *l*, and when the handle is set vertical, both gears *f* and *g* are out of mesh with the gear *e*, and there is no feed.

25. Behind the bevel gear *e*, Fig. 10, is a tumbler gear *m* that may be moved so as to mesh with either the cross-feed gear *n* or the gear *b* of the lengthwise feed. The tumbler gear is shifted by moving the knob *o* in the slot *p*. When it is at the top of the slot, the automatic lengthwise feed is engaged, and when it is at the bottom, the cross-feed is made automatic. The split nut is shown open at *i*. It consists of two parts that slide in vertical guides *q*. When threads are to be cut, and the carriage is to be moved by the lead screw and the nut, the handle *r* at the front is thrown over, thus moving the halves of the split nut in their guides, and drawing them together around the lead screw. The bevel pinions *f* and *g*, of course, are both



(a)

(b)

FIG. 10

out of mesh with the gear *e* when the split nut is closed on the lead screw.

26. The type of apron shown in Fig. 11 is operated by both a lead screw and a feed-rod. The lead screw passes through the split nut *a*, which is closed on it when threads are to be cut. The lead screw has no keyway, as it is used to drive the carriage only for screw cutting. The feed-rod *b* passes through the two bearings *c* at the bottom of the apron, and has a keyway throughout its length. The two worms *d* and *e* are carried by the bearings *c*, and slide along the feed-rod as the carriage moves; but they are keyed so that they must rotate with the feed-rod. The worm *d* drives the worm-wheel *f*, which is on the same shaft as the hand wheel *g*. A small gear on this shaft, behind the worm-wheel *f*, drives the wheel *h*, and so turns the pinion *i* that gears with the rack on the bed of the lathe. The hand wheel is used to move the carriage by hand. When the automatic feed is required, a knob at the front of the hand-wheel shaft is turned, thus drawing the cone clutch *j* into contact with the gear *f*. The cone *j* is fast to the hand-wheel shaft, and when it is drawn into the gear *f*, the latter turns the shaft, and so drives the gear *h*, thereby moving the carriage. A similar cone clutch *k*, operated by a second knob at the front, may be engaged with the worm-wheel *l*, which is driven by the worm *e*. The worm-wheel *l* and the gear *m* are thus locked together, and the cross-feed is driven automatically through the idler *n*.

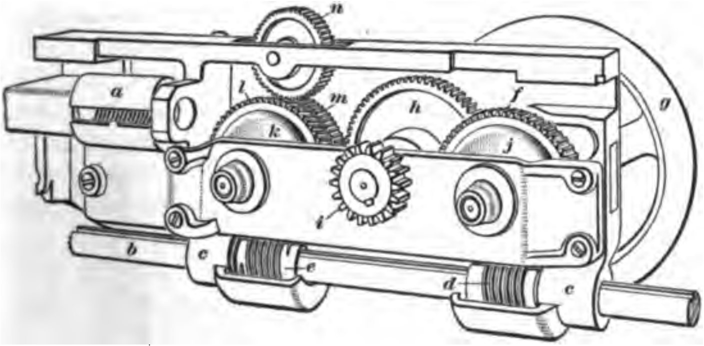


FIG. 11

LATHE ATTACHMENTS

TYPES OF RESTS

27. Rise-and-Fall Rest.—Various means are adopted for adjusting the height of the tool, depending on the style of lathe and carriage. Fig. 12 shows a very common rest used on small sizes of lathes. This is known as the rise-and-fall rest. It is composed of a lower part *a* resting on the bed of the lathe, and an upper part *b* hinged at the points *p*, and carrying the tool block. By turning the adjusting screw *s*, the upper part may be raised or lowered, and the tool set at any desired height. This is one of the most convenient forms of tool rest used for small work. A weight is frequently attached to the under side of the cross-slide *b* by a link passing through the bridge *a*. The weight should be heavy enough to hold the top part down. Lathes fitted up in this manner are called *weighted-rest lathes*. In some cases the weight is replaced by a coiled spring attached to the rest, and to a holder projecting down from the saddle bridge.

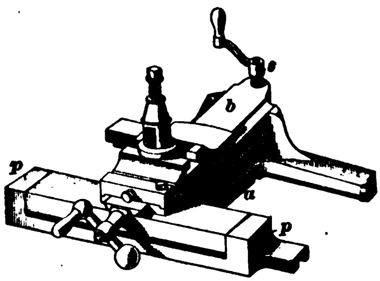


FIG. 12

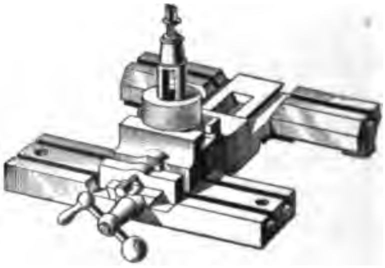


FIG. 13

28. Plain Rest. Another type of tool rest, known as the plain rest, is shown in Fig. 13, and is used principally on the larger lathes. The height of the tool point is adjusted before clamping in the tool post, by means of wedges, washers, or rings under the tool. These rest on the nurled ring shown in the illustration.

29. One style of adjustment commonly used for the tool is shown in Fig. 14. The tool rests on a chip *a* that is convex on its under side and fits the top of a concave ring *b* that rests on the tool block. The tool point *o* can be set at any height within given limits, and the chip *a* under the tool will rock to a position that will give a flat bearing for the tool. There are numerous other methods of tool adjustment that vary little in principle, and accomplish the same purpose.

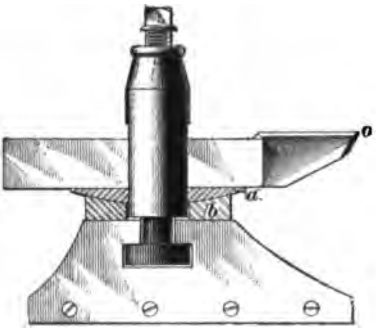


Fig. 14

30. Compound Rest. On the cross-slide of the lathe, a compound rest is usually provided. As shown in Fig. 15, the cross-slide *a* has swiveled on it a graduated plate *b* that can be set at any angle to the slide. A slide *c* on the top of the base *b* carries the tool post or tool clamp *d*, and is moved by the feed-screw *e*. On large lathes the compound rest is geared for power feed, and is used mainly for turning tapers that are beyond the range of the taper attachment. The rest is set to the required angle by loosening the clamp bolts, and swinging the slide *c* and the base *b* on the cross-slide *a*. The bottom jaw of the tool clamp is made concave to receive a convex chip. The chip is checkered on its upper surface, where the tool rests, and can be tilted in either direction to alter the height of the tool point.

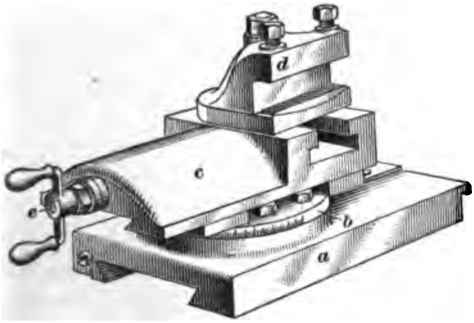


Fig. 15

TAPER ATTACHMENT

31. Construction.—The taper attachment, one form of which is shown in Fig. 16, may be used when a taper is to be turned on the lathe. A bracket *a* is bolted to the back of the saddle, and has in its top a groove that is parallel to the V's of the lathe bed. A slide *b* fits in the groove, and may move endwise. At one end is an offset *c* that is secured rigidly to an anchor *d* that may be clamped to the back V at any point. A bar *e* is pivoted at its middle point on the top of the slide *b*, and at its ends has clamping bolts that move in slots *f* cut in the slide. The taper bar *e* may thus be swung so that it will be parallel to the lathe V's, or so that it will stand at an angle to them. A graduated scale is marked on the slide at *g*, and a pointer is formed on the end of the taper bar, so that the bar may quickly be set to give the desired taper. The graduations usually indicate the taper in inches per foot, but occasionally they give it in degrees.

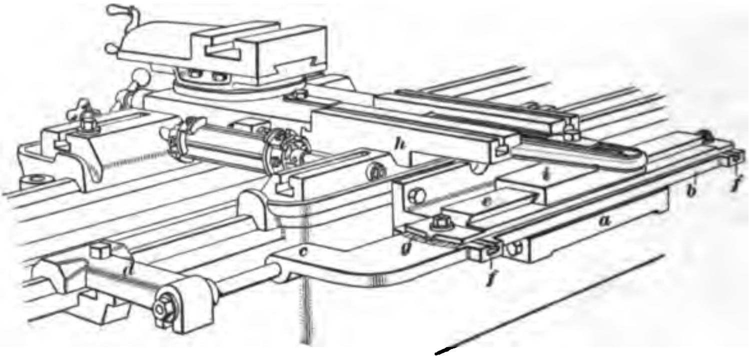
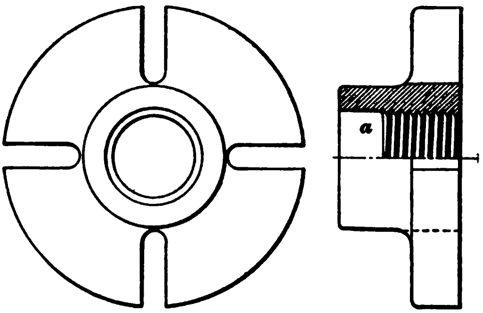


FIG. 16

32. Operation.—When the taper attachment is to be used, the cross-feed nut is disconnected from the cross-feed slide *h*, Fig. 16, and the latter is rigidly connected to the slide *i* on the taper bar. The taper bar is set to the desired taper, and the anchor *d* is clamped to the bed. Then, as the carriage moves along the bed, the slide *i* will move along the taper bar, which is set at an angle to the **V**'s, and as a result the cross-slide *h* will be moved crosswise on the carriage. This will move the tool closer to the axis of the work or farther from it, and the desired taper will be turned. In some makes of lathes the bracket *a* at the back is made adjustable, and is clamped firmly to the bed in the desired position, instead of being fastened to the carriage.

SPINDLE ATTACHMENTS AND HOLDING DEVICES

33. Face Plates.—A lathe is provided with two face plates for general work. The plates are bored and threaded to fit the thread on the nose of the spindle, and the back end is generally counterbored to fit a plain cylindrical part of the spindle at the inner end of the thread, as shown at *a*, Fig. 17 (*a*). The smaller of the two face plates is used to drive work that is held between centers. It has one or more radial slots cut in the flange to receive the tail of the dog that drives the work. The larger face plate is usually made with **T** slots extending from the hub to the edge, and with short slots extending through the plate between the **T** slots. It is used mainly for holding work to be machined accurately, but is also used as a driver when the smaller plate cannot be employed.



(*b*) FIG. 17 (*a*)

34. Lathe Centers.—The live center in the headstock spindle turns with the work, but the dead center in the tailstock spindle is stationary with respect to the work. The centers are made of carbon tool steel so that the points may be hardened to resist wear. Both should be very hard, and a grinder should be provided for grinding them in position in the live spindle, when they are used for heavy work or with high-speed tools. If a lathe is used for light work, it is customary to draw the temper of the live center so low that it can be trued by a

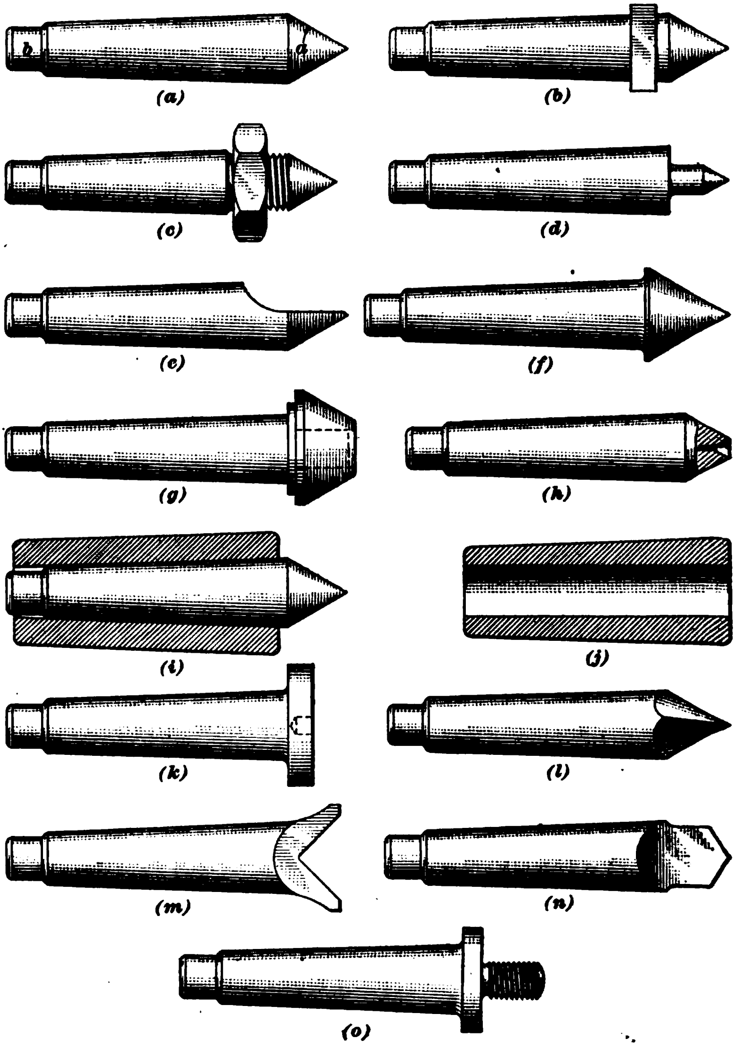


Fig. 18

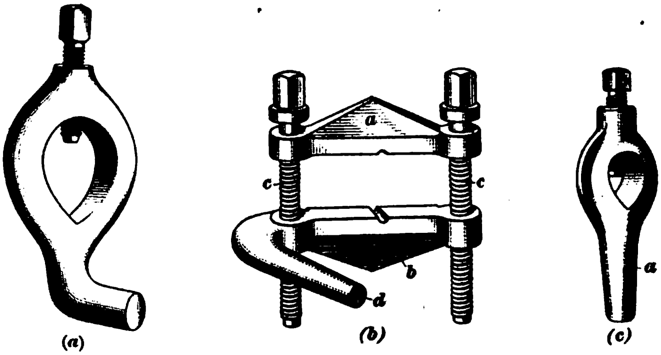
turning tool held in the tool post. This is also done when no center grinder is available.

35. Center Angle.—The angle of the conical end of the lathe center, as shown at *a*, Fig. 18 (*a*), is usually 60°, but for very heavy work an angle of 75° gives a stronger center. The body of the center is tapered to fit the spindle taper, which is usually $\frac{5}{8}$ inch per foot, and the back or small end *b* is turned smaller than the center hole, so that when it is battered or upset by the rod used in removing it, it will not bind in the hole. If the inner end of the center was made plain, and should become battered or upset, it would not fit the tapered hole in the spindle, and the hole would soon be ruined. The reduced end will not upset enough to cause trouble.

36. Forms of Centers.—Various centers and tools used in lathe spindles are shown in Fig. 18. The simplest form of center is shown in (*a*). It is driven out of the live spindle by passing a rod through the spindle, and it is backed out of the dead spindle by running the spindle back until the back end of the center strikes the end of the spindle screw. The center (*b*) is used in a solid spindle, and a wrench is applied to the square formed on the center, so as to remove the latter from the spindle. The center (*c*) is drawn out of the spindle by the nut shown, which is screwed against the end of the spindle. This nut usually has 14 or 16 threads per inch. A projecting part of smaller diameter is formed on the center (*d*), which is used when an arbor does not extend through a hole in a piece of work. The half center (*e*) has nearly half of its diameter cut away, leaving a flat surface. It is placed in the dead spindle with the flat surface toward the tool, and the cut-away part allows the side tool to be run to the full depth of its cut without interfering with the center.

37. If the work has a hole through it, as in the case of a pipe, or if the center hole is unusually large, the pipe center (*f*), Fig. 18, is used. The form shown in (*g*) is a revolving center. As indicated by the dotted lines, a stud is formed on the end of the shank to fit a hole in the conical tip. The tip then turns with the work, and rotates on the stud. The female center (*h*) is used with work that has pointed ends, and for work that is too small to have center holes drilled in it. A very large spindle is often provided with a tapered bushing (*i*) that fits the taper of the spindle, and allows a smaller center to be used in it. It is made of soft steel, which is cheaper than making a large center wholly of tool steel. A similar bushing, shown in (*j*), is made with a straight hole, and when placed in the tapered hole in the live spindle, serves as a guide for a boring bar held in the tailstock. The pad center (*k*) is used in the tailstock spindle when thin or flat pieces are to be drilled.

38. The square center shown in (*l*), Fig. 18, has four faces, and the opposite corners make an angle of 60°; it is used to ream a center hole. The work is placed on the live center, and held with a dog, as for turning, and the square center is put in the dead spindle. The butt end of a tool held in the tool post is then run up to the work, and as the latter revolves the square center is fed into the center hole. The tool and the center maintain fixed positions relative to each other, so the center hole will be true with the circumference. The forked center (*m*) is used in the dead spindle to support and guide round work while it is being drilled by a drill held in the live spindle. The starting drill (*n*) is a center flattened on two sides, and formed into a flat drill. It is used in the dead spindle to start holes true where they are to be drilled by a less rigid tool, such as a long twist or flat drill. The thread mandrel or center arbor (*o*) is a work holder, usually threaded, and used in



(*a*) (*b*) (*c*)

FIG. 19

the live spindle for holding nuts or other internally threaded machine parts.

39. Lathe Dogs.—A lathe dog, known also as a *carrier* or *driver*, is a device that is slipped over and clamped to the end of a piece of work. A tail, or projection, on the dog enters a slot in the face plate, or engages a stud projecting from the face plate, and the work is thus caused to rotate. The bent-tail dog shown in Fig. 19 (*a*) is most commonly used for round work. It is a steel forging, with a hole to receive the end of the work. and a setscrew to clamp it tightly. The bent end, or tail, enters a slot in the face plate. The clamp dog shown in (*b*) consists of two parts *a* and *b* that may be drawn together by the screws *c*, to clamp work placed between them. A tail *d* on the part *b* serves to drive the work. The straight-tail dog shown in (*c*) requires a stud to be fastened to the face plate so as to engage with the tail *a* and rotate the work.

LATHE FOR HEAVY WORK

40. Construction.—An engine lathe including most of the details that have already been described, and of such heavy design as to be well suited for heavy work with high-speed steel tools, is shown in Fig. 20. It is driven by an electric motor *a* bolted on top of the headstock frame, which is made hollow to form a guard for the gearing. The lower half *b* contains oil to lubricate the gears. The motor is controlled by a controller box at the rear, which is operated by the hand wheel *c* through the shaft *d*, and other connecting gearing. Power is transmitted to the initial driving shaft through the gear train *e* at the left end of the headstock. A powerful friction clutch operated by the lever *f* enables the initial driving shaft to be either connected to the gear train *e* or disconnected from it, thus starting or stopping the lathe. If the lathe is to be driven by a belt instead of by a motor, the lower gear of the gear train *e* is replaced by a plain pulley. The head contains gears that may be moved by the levers *g*, *h*, and *i*, thus altering the speed at which the work spindle is rotated.

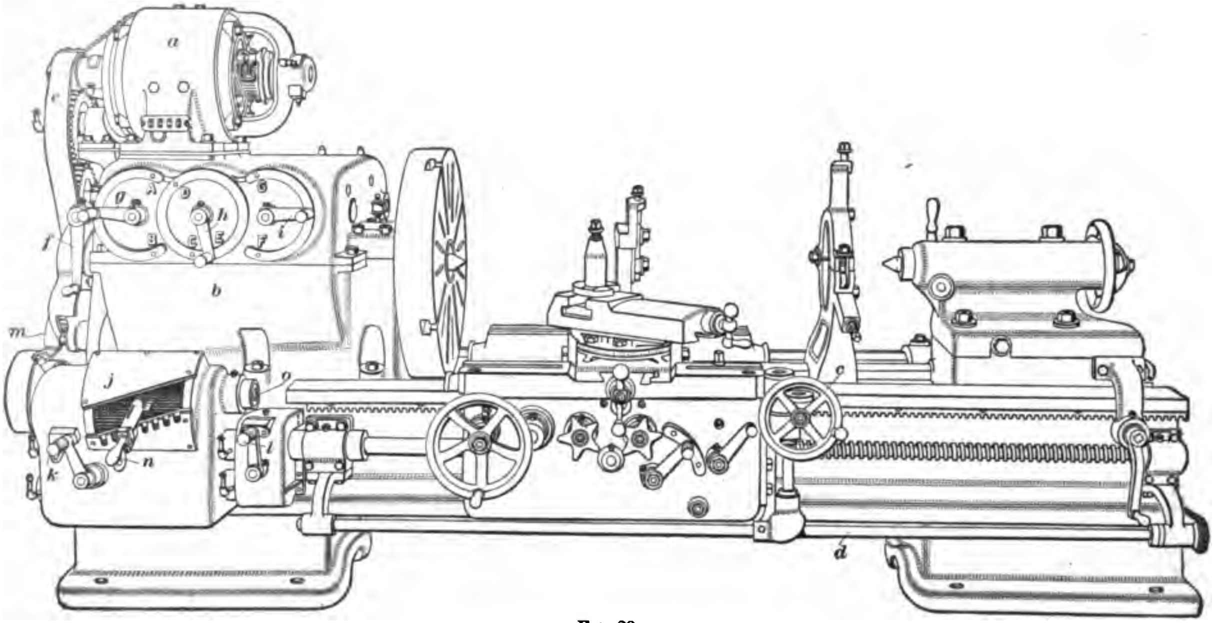


FIG. 20

41. Geared Head.—A diagram of the gearing contained in the head of the high-duty lathe is shown in Fig. 21. This diagram shows the connections between the driving pulley and the work spindle. The initial driving shaft *a* is driven from the pulley *b* through the clutch *c*, and carries a pair of slip gears *A* and *C* mounted on the same sleeve. These slip gears are

Runs	Speeds	Ratios	Levers
ABDH	260	1 : 1	*B–E–G*
ABEG	181	1.4086 : 1	*B–D–G*
ABF	133	1.984 : 1	*B–C–G*
CDH	93	2.795 : 1	*A–E–G*
CDEG	65	3.937 : 1	*A–D–G*
CDBF	47	5.546 : 1	*A–C–G*
ABDHIKLM	33	7.812 : 1	*B–E–F*
ABEGIKLM	23	11.005 : 1	*B–D–F*
ABFIKLM	17	15.504 : 1	*B–C–F*
CDHIKLM	12	21.836 : 1	*A–E–F*
CDEGIKLM	8.3	30.760 : 1	*A–D–F*
CDBFIKLM	6	43.330 : 1	*A–C–F*

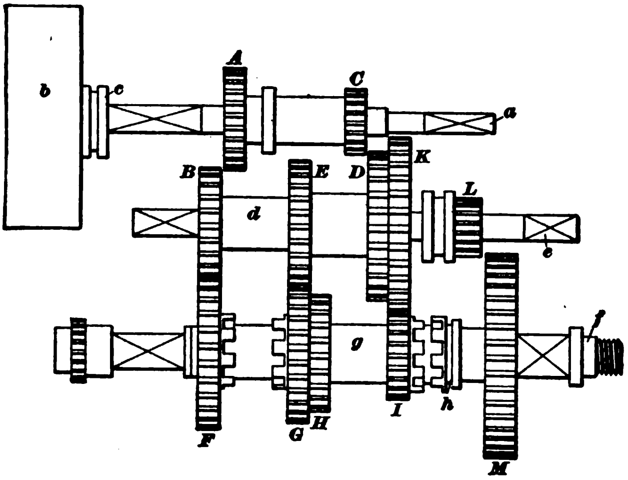


FIG. 21

moved along the shaft *a* by the lever *g*, Fig. 20, and may be brought into mesh with the gears *B* and *D*, Fig. 21. The three gears *B*, *E*, and *D* are fixed to the sleeve *d*, which can rotate freely on the shaft *e*, but cannot move endwise. The gear *K* is keyed to the shaft *e*, and the pinion *L* is splined to it so that it can be slid endwise, but must turn with the shaft. The work spindle *f* has a sleeve *g* loose on it. On the sleeve *g* are splined the two slip gears *G* and *H*, and the third gear *I* is keyed to the sleeve *g*. The clutch gear *F* is loose on the spindle *f* and the gear *M* is keyed to it. The clutch *h* is splined to the spindle *f*, and may be thrown in so as to engage with the sleeve *g*, and thus cause the spindle to turn with the gears *G*, *H*, and *I*. The clutch *h* is moved at the same time as the pinion *L* by the lever *i*, Fig. 20. When the pinion *L*, Fig. 21, is in mesh with the gear *M*, the clutch *h* is free, and when the clutch *h* is engaged, the pinion *L* is free. The central lever *h*, Fig. 20, controls the movements of the slip gears *G* and *H*.

42. The table given in connection with the diagram, Fig. 21, contains four columns. The first gives the runs, that is, the series of gears used to obtain a given speed. The second column gives the speed of the spindle in revolutions per minute. The third column shows the ratio of speeds of the initial driving shaft and the spindle, that is, the number of turns made by the initial driving shaft to one of the spindle. The last column gives the holes to which the levers must be set, and these holes refer to the three sets shown at the front of the headstock in Fig. 20. For example, suppose that a spindle speed of about 50 revolutions per minute is required. The nearest value to this in the table, Fig. 21, is 47, which is obtained with the gears *C*, *D*, *B*, and *F* in mesh. The holes called for are *A*, *C*, and *G*. The lever *g*, Fig. 20, is therefore set to the hole *A*, which throws the slip gear *C*, Fig. 21, into mesh with the intermediate gear *D*. The lever *h*, Fig. 20, is set to the hole *C*, which throws the clutch on the gear *G*, Fig. 21, into mesh with that on the gear *F*. The lever *i*, Fig. 20, is set to the hole *G*, which throws the clutch *h*, Fig. 21, into mesh with that on the gear *I*. The motion is then transmitted from the gear *C* to the gear *D*, the sleeve *d*,

Runs	Ratios	Levers
Direct to screw	1 : 1	*B–C*
A B C D	1 : 2	*A–C*
E F G H	1 : 4	*B–D*
A B C D E F G H	1 : 8	*A–D*

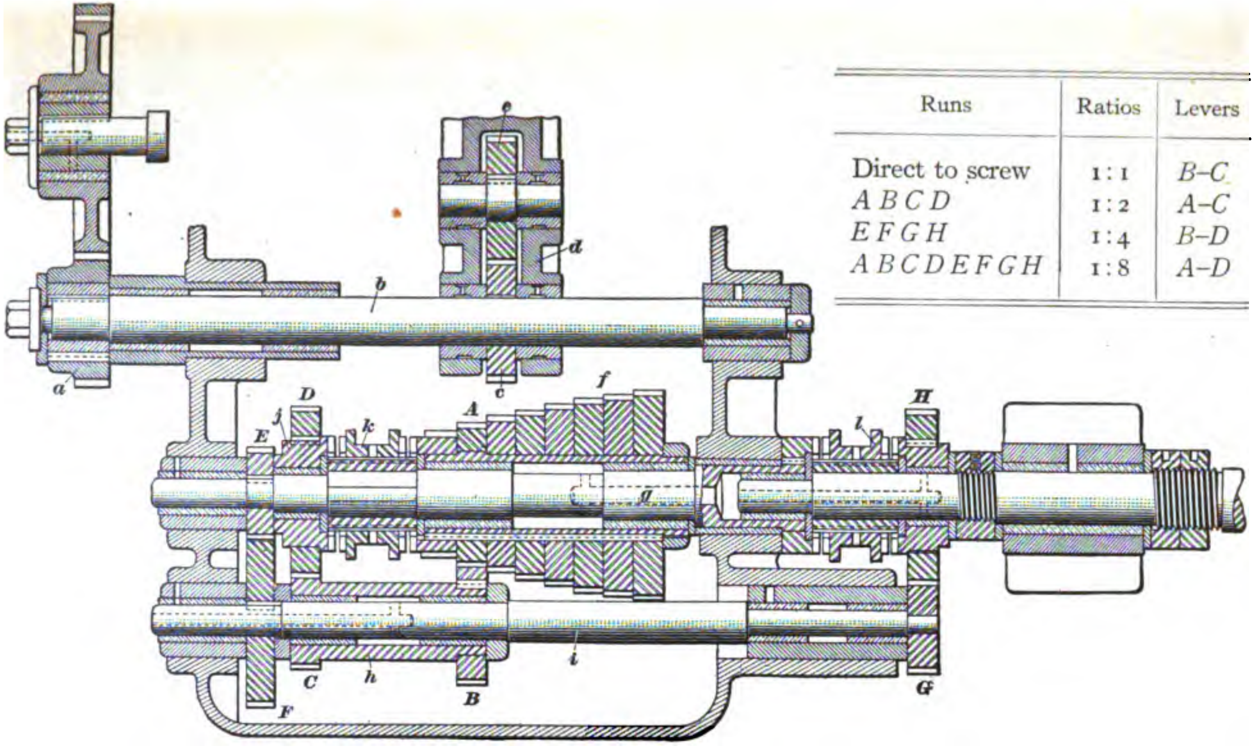


Fig. 22

the gear *B*, the gear *F*, the sleeve *g*, the gear *I*, the clutch *h*, and thence to the spindle *f*.

43. Quick-Change Gearing.—The rate of motion of the carriage for turning or for cutting screws may be varied by using the change-gear box *j*, Fig. 20, in connection with back gearing controlled by the levers *k* and *l*. A sectional diagram of the gearing in the change-gear box is shown in Fig. 22. The pinion *a* on the end of the tumbler shaft *b* is driven from the work spindle through a train of gears beneath the guard *m*, Fig. 20. This train is in all respects like that between the spindle and the lead screw of the lathe shown in Fig. 3. But whereas the speed of the lead screw in Fig. 3 is changed by using change gears of different sizes on the stud and the screw, the changes in the lathe in Fig. 20 are obtained by using the change-gear box and the back gearing. The lever *n* is connected to a sliding tumbler gear that may be moved endwise on the tumbler shaft *o*, and put in mesh with any one of eight gears forming a cone in the gear-box. In this way eight different speeds of the lead screw are obtained through the cone. But the back gears controlled by each of the levers *k* and *l* can be used to give two changes of speed in connection with each gear on the cone. There are thus 32 lead-screw speeds obtainable through the change-gear box and the back gearing.

44. On the tumbler shaft *b*, Fig. 22, is a pinion *c* that can be slid along the shaft, but must turn with it. The pinion *c* is held in the forked end of a lever *d* that corresponds to the lever *n*, Fig. 20. The pinion *c*, Fig. 22, meshes with a pinion *e* that is also carried by the lever *d*, and that can be dropped into mesh with any one of the eight gears forming the cone *f*. These eight gears are keyed to a sleeve that is loose on the lead-screw shaft *g*. The back gears *B* and *C* are fixed on a sleeve *h* that is loose on the back-gear shaft *i* and the back gears *F* and *G* are keyed to the shaft *i*. The gear *D* is fastened to a sleeve *j* that is loose on the shaft *g*, and the pinion *E* is fast to the shaft. The clutch *k* is splined to the shaft *g*, and may be engaged with the cone *f* or the sleeve *j*. The gear *H* is keyed to a sleeve that is loose on the lead screw, and the clutch *l*, which is splined to the lead screw, may be engaged with the gear *H* or with the end of the shaft *g*.

45. The table given in Fig. 22 shows the speed ratios obtained through the back gears *A*, *B*, *C*, *D*, *E*, *F*, *G*, and *H*, and gives the runs and the holes to which the levers *k* and *l*, Fig. 20, must be set. The eight changes that furnish the coarsest feeds are obtained directly through the cone gears, without using the back gears at all. In these cases, the levers *k* and *l*, Fig. 20, are set to the holes *B* and *C*, respectively. The driving is then done from the shaft *b*, Fig. 22, through the gears *c* and *e* to one of the cone gears, through the clutch *k* to the shaft *g*, and through the clutch *l* to the lead screw. The eight gears in the cone thus give eight different speed changes when the drive is direct, that is, when no back gears are used. With the run shown in the second line of the table, the levers are set to *A* and *C*. This causes the clutch *k* to engage the sleeve *j*, and the clutch *l* to engage the end of the shaft *g*. Thus, after driving through the cone, power is transmitted through the back gears *A*, *B*, *C*, and *D* to the sleeve *j*, then to the clutch *k*, thence through the shaft *g* and the clutch *l* to the lead screw. The use of these four back gears makes the lead-screw speed half as great as when the drive is direct; but as the drive may be through any of the cone gears, there are eight speeds possible with the back gears *A*, *B*, *C*, and *D*, depending on which of the cone gears is used. The two remaining runs in the table decrease the speed to one-fourth and one-eighth that obtained by direct driving.

LATHE CHUCKS

46. Action.—Small regular work may be held best in the lathe chuck, a form of which is shown in Fig. 23. It consists of a cast-iron disk that has radial slots in its face, in which slide a number of jaws. The work is held by being placed against the face and then having the jaws moved in or out to grip it. The chuck itself is screwed on the nose of the lathe spindle, in place of the face plate. The jaws may be moved by a scroll, or by screws, as in Fig. 23. In Fig. 24 is shown a section of the chuck in Fig. 23, with one jaw and its screw removed and placed above the chuck. The lathe chuck of this type is made as large as 3 feet in diameter. Work that would require the use of very large chucks may be better operated on by fastening or bolting it to the face plate of the lathe. Chucks are made with two, three, or four jaws. Chucks similar to that shown in Fig. 24 may have the jaws reversed by unscrewing and putting them in in reversed position.

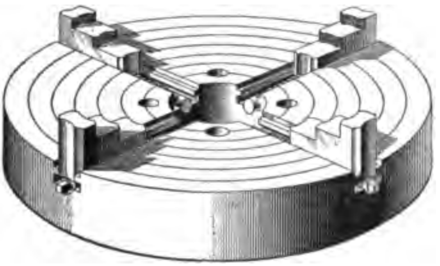


Fig. 23

47. Classification of Chucks.—Chucks are classed as *independent*, *universal*, and *combination*, *chucks*. Independent chucks are so arranged that each jaw is moved with an adjusting screw independent of the other jaws. Universal chucks are so constructed that when one jaw moves, the others move in the same direction a corresponding distance. Combination chucks are so made that they may be used either as independent or as universal chucks.

48. Independent Chucks.—Any irregular shape can be accommodated by the setting of the jaws of the independent chuck. It also has the advantage that, owing to the separate adjustment of each jaw, a turned piece can be so set in it that the surface will run true. This usually cannot be done in a universal chuck. If the independent chuck is used on work of regular shape, the time required to set the work can be reduced by marking two of the jaws of a four-jaw chuck after the first piece has been

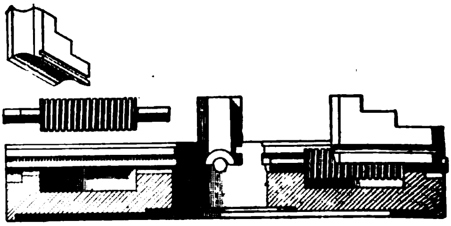


Fig. 24

set true. When the piece is finished, it can be removed by loosening the marked jaws, the succeeding piece can be placed in position, and the marked jaws tightened. This will usually bring the work about true. It should be tested, however, and any necessary corrections made. This operation may be repeated for any number of pieces that are alike and work may be set central almost as quickly as in the universal chuck. Chucks used for general work on the lathe are usually of the independent type if they are 12 inches or more in diameter.

49. Universal Chucks.—The chucks used on small lathes for holding regular work are usually 6- or 8-inch universal chucks. They grip round work quickly, and they center it near enough in most cases. Larger chucks are used for some classes of work; but they wear with use, so that they will not hold work as true as the independent chuck. A universal scroll chuck is shown in Fig. 25, illustrating the two positions in which the jaws can be used. The jaws of the scroll chuck have what are practically square teeth *a* on their bottoms, and these engage a scroll, or square spiral thread cut on a disk at the back of the jaws. The back side of this disk has a bevel gear cut on it which is operated by pinions, the outer end of one being shown at *b*. When the pinion is turned by a square key that fits in its end, the bevel gear is rotated, thus rotating the spiral thread, and causing the jaws to move toward or away from the center of the chuck.

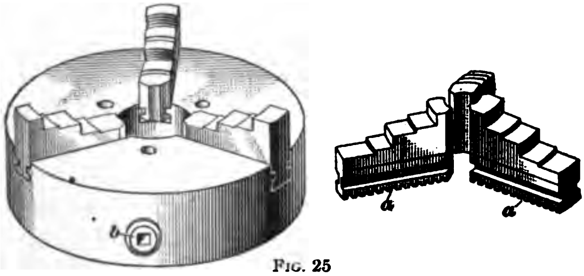


FIG. 25

50. Combination Chucks.—A combination chuck with a quarter section removed from the back is shown in Fig. 26.

A pinion *a* is cut on each adjusting screw, and these pinions engage with a circular rack *b* in the back of the chuck. When one adjusting screw is turned, the rack is rotated, and each screw is turned an equal amount, thus moving each jaw a corresponding distance. To make this chuck independent, the rack must be lifted out of mesh with the pinions on the screws. The ring *c* rests against the back of the rack *b*, and cams *d* project from the back of the ring. When the ring is partially rotated by means of the knob *e*, the cams *d* drop into pockets, thus allowing the ring and the rack to move away from the pinions sufficiently to disengage. When this is done, each screw is disengaged, and the chuck is independent. When the ring is partly rotated in the opposite direction, the cams lift the ring and rack so that the latter again engages the pinions, and the chuck is again universal.

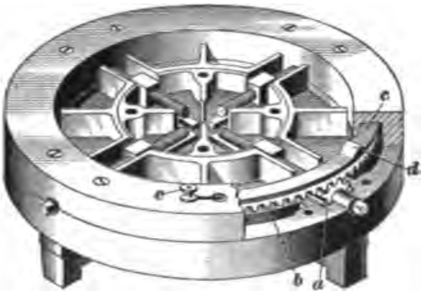


FIG. 26

51. After using a combination chuck as an independent chuck for irregular work, the jaws will be out of true. To set the jaws true, each must be adjusted to a circle that is drawn on the face of the chuck, and then the rack must be thrown into gear. Combination chucks can be used to good advantage for some classes of irregular work. The chuck is made independent, and after the work is once set true, the combination can be thrown in. When the work is removed, the jaws will all open together. If the next piece of work is set in the chuck in the same position relative to the jaws as the first, the jaws can be tightened and the work will run true, as the previous piece. A universal chuck may be constructed like the one shown in Fig. 26 with the ring *c* left out and the rack *b* in contact with the gears, or the jaws may be moved by a scroll. The ordinary drill chuck is also used on the lathe for such drilling operations as may be necessary.

52. Setting Work in an Independent Chuck.—To set a round piece in an independent chuck, if the work is at all heavy, it can be held against the chuck by using a block of wood between the work and the dead center, as shown in Fig. 27. This will prevent the work from falling out while the jaws are being adjusted. The jaws are tightened only enough to hold the work. The lathe is started at a moderately fast speed, and the work is tested by holding chalk near its face. If the work does not run true, the chalk will touch only the high side. This indicates that the work should be moved. If the chalk touches the work as shown by the line *a b*, it would indicate that the jaw opposite jaw *1* should be loosened, and jaw *1* tightened, thus moving the work across the face of the chuck. If the chalk touches between the two jaws, then the two opposite jaws must be loosened, and the two front ones tightened a corresponding amount. The amount that each jaw is moved should be observed, as it will help to determine the amount of subsequent movements. This is continued until the chalk touches at points evenly all around.

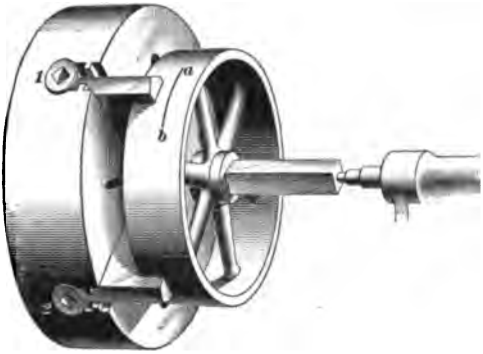


Fig. 27

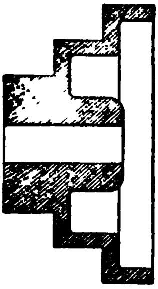


Fig. 28

53. When the work is to be turned or faced on a number of faces, each face should be tested in setting the work before beginning to turn any one face. For example, take the cone pulley, Fig. 28. Here the hole must be bored true, and the inside and outside of the cone bored and turned. If the casting is perfectly true, the work may be set by any one face, and the others will naturally run true; but this is not often the case. All parts should be tested to see whether there is enough stock and whether all surfaces run true enough to turn to size.

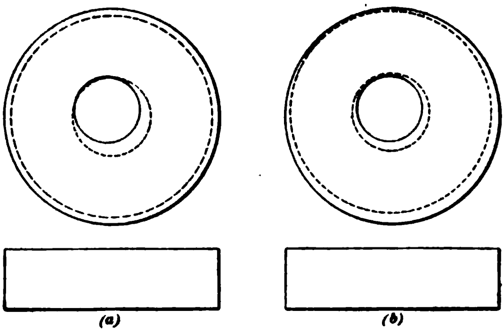


FIG. 29

54. Example of Chucking.—Suppose that a disk, as shown in Fig. 29 (*a*), with a hole cored very much to one side, is to be bored, and turned to a given size. If set in the chuck so that the outside runs perfectly true, the cored hole would be so out of true that it could not be finished. If the cored hole is set to run true, then the outside could not be finished all over. In such a case, the work should be so set that both the outside and the cored hole run enough out of true to equalize the difference. By thus dividing up the eccentricity, or the amount by which the outside and the hole are out of center, it will be found that the work can be finished all over to the desired size, as shown by the dotted lines in (*b*) lying wholly within the outline of the work.

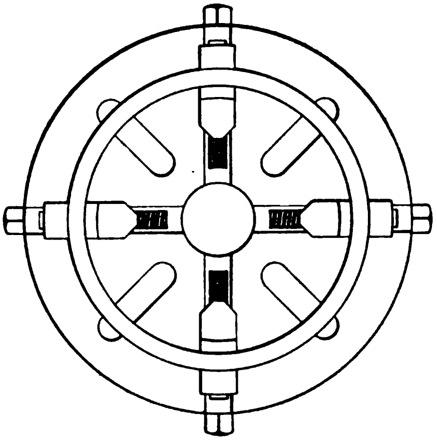


FIG. 30

55. Spring of Work From Pressure of Jaws.—When the work is light or frail, there is much danger of springing under the pressure of the jaws necessary to hold the piece. In gripping a piece, advantage should be taken of the shape of the work to have the jaws of the chuck come against the more solid parts. For example, in chucking a pulley, it should be so set that the jaws come opposite the arms of the pulley. The pulley is later put on a mandrel and turned, which will correct the springing. Suppose that a ring is held in the chuck, as shown in Fig. 30. When the jaws are tightened, the work is sprung opposite each jaw. If a cut is taken, the work will be bored true and round while under pressure of the jaws. When this pressure is relieved, it will be found that the work will no longer be true, but will spring back to its normal shape. This will cause the work to be out of round, as shown in Fig. 31, the dotted lines indicating the true circle. In such cases the jaws of the chuck should be loosened and the ring reset before taking the finishing cut. The jaws should be tightened so that the pressure will be just sufficient to hold the work during the light finishing cut.

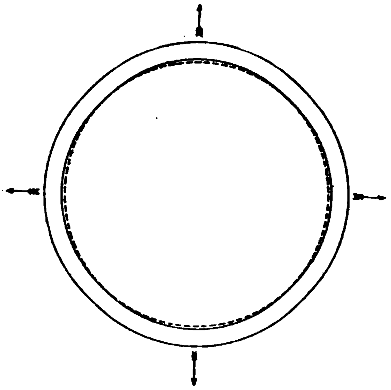


FIG. 31

56. Advantages of Different Chucks.—Independent chucks are generally stronger and better adapted to irregular forms of work than either of the other types. Universal chucks are best adapted to regular work; they save much time because of the ease and rapidity with which the work may be centered. Combination chucks answer for both purposes, but require a little more care to keep them in proper condition.

USE OF CHUCKS

57. Selection of Chuck.—If the hole to be bored has the same center as the outside of the work—that is, is concentric with the outside of the work—the universal chuck can be used. If the work does not run satisfactorily, it can be partly turned around in the chuck, and tried in various positions. If this is not sufficient to make the part to be bored run sufficiently true, pieces of paper or brass can be placed between a jaw of the chuck and the work. When this amount of trouble is necessary, an independent chuck would be the better one to use.

58. Drill chucks of all kinds are placed on shanks fitting the holes in lathe spindles, and are used for such work as drilling holes and filing pins. The heavier drill chucks are sometimes employed for light turning; but as this is liable to spring them, they should not be used for this purpose.

59. Care in Use of Chucks.—In putting a chuck on the lathe, its thread and that on the spindle should be cleaned; then it should be held carefully against the nose of the spindle while the belt is pulled by hand. It is not good practice to start the lathe by power, and hold the chuck against the spindle, expecting the thread in the chuck to catch squarely on the spindle thread; neither is it good practice to let the spindle screw into the chuck up to the thread with a bang. This often causes the chuck to stick so tightly to the spindle that it becomes difficult to remove. When the chuck does stick on the spindle, it may be loosened by standing a block of wood on the back **V**'s, and allowing a jaw of the chuck to come down on this block. The lathe is then put on the slowest speed, and run backwards by hand, which loosens the chuck; one or more quick raps of the jaw on the block will aid greatly.

60. Chucks should not be hammered, nor should a piece of pipe be used as an extension to the chuck wrench to give greater leverage; in either case, the chuck may be sprung or broken. In gripping a large piece, the jaws should not be run out so far that only a small part of the thread holds on the screws, as the threads may be damaged, and the body of the chuck may be sprung.

SPECIAL CHUCKS

61. Some work is of such shape that the ordinary lathe chuck will not hold it with sufficient rigidity to take heavy cuts. In this case, special chucks may be made, when there are enough pieces to be turned to warrant the cost. For example, the cone pulley shown in Fig. 28 may best be held in a special chuck, such as that shown in Fig. 32. This chuck consists of a bell-shaped casting *a* that is fitted to the spindle *b* of the lathe. The outer end is bored to receive the work *c*, which is held in place by setscrews *d* at the sides. This form of chuck holds the work with great rigidity and makes possible the taking of heavy cuts that otherwise could not be made. It is also used to a large extent for special manufacturing purposes in many shops. For special work, other forms of chucks may be devised that depend on the shape of the work.

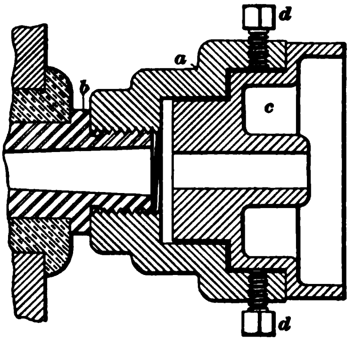


FIG. 32

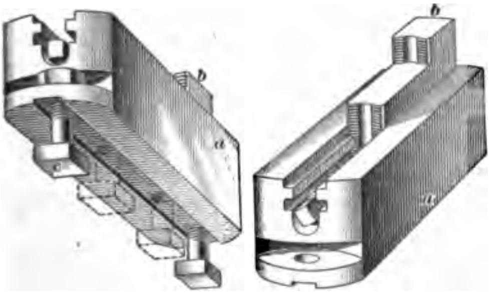


FIG. 33

62. Chucking on Face Plate. When the work is large or heavy, or for other reasons cannot be held in the chuck, it may be fastened to the face plate by means of bolts, straps, and parallels. Work on the face plate must be secured firmly, so that it will not slip because of its weight or the pressure of the tool.

63. Adjustable Jaws for Face Plates.—For securing work on the face plate, and to enable the operator to chuck similar pieces successively with the least amount of labor, adjustable jaws are frequently clamped on the face plate. The adjustable jaw usually consists of a block, as *a*, Fig. 33, in which the jaw *b* works. The blocks are clamped to the face plate by means of **T** bolts *c*. This really makes the face plate a special form of chuck. A face plate fitted with these adjustable jaws is shown in Fig. 34. The jaws have the advantage that they can be placed evenly, as shown, or they can be arranged unevenly to accommodate irregular work, either placing some of the jaws nearer the center than others, or spacing them irregularly in the different slots in the face plate. The entire piece that is attached to the face plate is usually called a *jaw;* but in reality only the portion *b* is the jaw, and these pieces *b* may be made reversible, thus giving a greater range of work that can be held by this device.

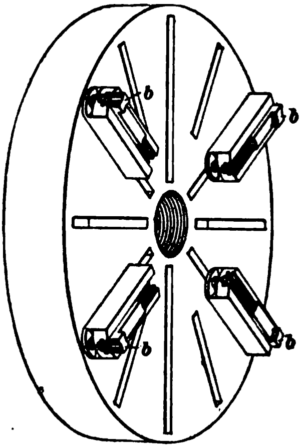


FIG. 34

64. Sometimes, simpler forms of jaws may be used, as shown in Fig. 35. These consist of **L**-shaped castings *s* bolted to the face plate and provided with setscrews for securing the work. The shoulder below the point of the setscrew should be turned off so that the dimension *a* is the same on all of them. This will enable the operator to place work against these shoulders during chucking.

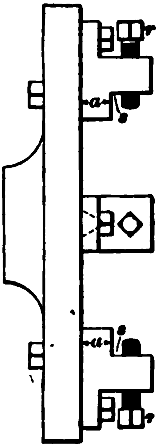


FIG. 35

65. Clamping Regular Work.—In Fig. 36 is illustrated a very simple method of clamping a large flange to a face plate when it is only desired to bore the hole in the center of the flange, and to face the hub *f*, the surface *r* being left rough. This method will do very well where the back face of the flange may be clamped directly to the face plate or on parallel blocks, and where but a single hub is to be operated on. If it becomes necessary either to face the surface *r* or to operate on a number of pieces, it is best to use jaws similar to those illustrated in Figs. 34 and 35.

66. Clamping of Rocker-Arm.—When it is desired to clamp a rocker-arm similar to the one shown in Fig. 37, three chucking-block jaws similar to those shown in Fig. 35 may be used. They are placed at *c* and bear against three sides of the large hub of the rocker-arm. The work is held securely against the face plate by means of the two clamps *d*, as shown in Fig. 37. Fig. 38 is a section on the line *a b*, Fig. 37, and shows the arrangement of the clamps and blocking; *e* is the arm, *d* are the clamps, *g* the blocks, and *f* the bolts. Care should be taken to see that the blocks *g* are of exactly the height of the work, so that the clamps *d* will set level or parallel to the face plate. The bolts *f* should be placed as close to the work as possible.

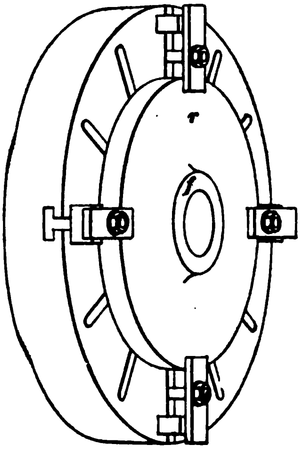


FIG. 36

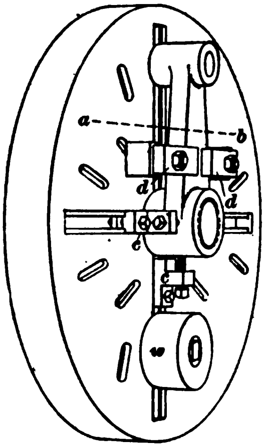


FIG. 37

67. If strain is brought on the work *e* by the clamps *d*, Fig. 38, it is evident that there will be danger of springing the arm between its hubs or bosses. To overcome this, a block is placed under the arm, on each side, as shown at *j*. In order to balance the portion of the rocker-arm extending to one side of the center and the clamps and bolts *d* and *f*, a counterweight *w*, Fig. 37, may be attached to the opposite side of the face plate, as shown, and adjusted in or out until it balances the whole exactly. Such work as this, which has a number of faces that must be finished in certain relations to one another, should be laid out before attempting to set it in the chuck or on the face plate. The work is to be bored to the circle indicated by the dotted line, and may be set so that it will run true with this circle by testing with a scriber or pointed tool held in the tool post.

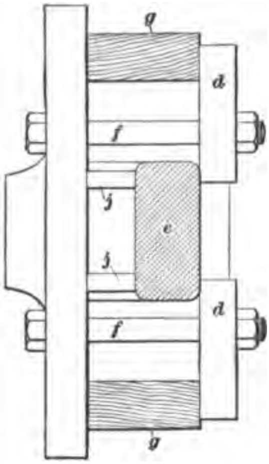


FIG. 38

68. Use of Paper on Face Plate.—When a finished surface is to be clamped against the face plate or any other metal surface, the danger of its slipping can be greatly reduced by putting a slip of paper between the two surfaces where each clamp is applied. If this precaution is not taken, it will be found almost impossible to clamp the work so that it will resist the action of the boring and turning tools.

69. Pulley Clamp.—Pulleys that must be bored and turned can be clamped by means of the arms. Fig. 39 illustrates a clamp intended for this purpose. The block *a* is bolted to the face plate and supports an adjustable clamp *c* having a turned portion that fits in a socket in the block *a*, and is secured by the setscrew *d*. The pulley arm *b* is held in the

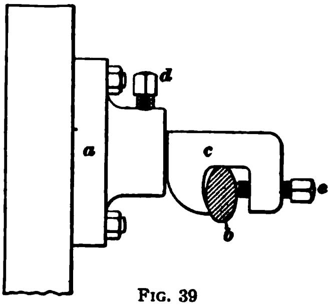


FIG. 39

clamp *c* by the setscrew *e*. Similar clamps can be devised for holding a great variety of irregularly shaped work.

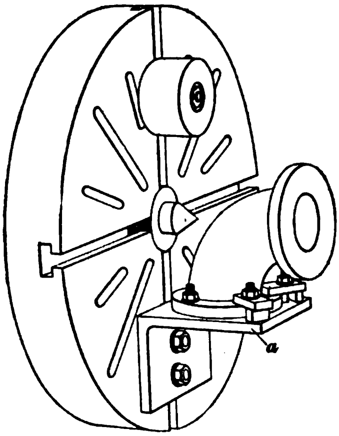


FIG. 40

70. Angle Plate.—A very convenient attachment for face-plate work is the angle plate, as shown at *a*, Fig. 40. This angle plate is so made that its two faces are at an angle of 90° with each other, and it is used when it is desired to finish two faces of a piece square with each other, as, for instance, the flanges of a pipe elbow. One face is clamped to the angle plate as shown. This holds the other face of the elbow in such a position that it will be cut square with the first face. This angle plate may be used to great advantage for many operations in face-plate work.

SOLID MANDRELS

71. In many shops the terms **mandrel** and **arbor** are understood to have the same meaning. More commonly, however, a mandrel is understood to be a centered shaft or spindle driven into the hole in a bored piece, so that the piece may be held between lathe centers while the outside is turned; it also means the straight or tapered form on which a blacksmith forges a ring, or a piece about which metal is cast. The term arbor is used mainly to denote the shaft or holder on which a saw or a milling cutter is placed, and by which it is driven.

72. Shape of Solid Mandrel.—A mandrel is commonly used on work having a bore 3 inches in diameter or less. The best form is the solid one made from tool steel, hardened and tempered, such as that shown in Fig. 41. It is made slightly under size at the ends, so that the dog may be put on.

The center holes should be carefully made so that they will not be injured by driving. Fig. 42 shows a section through the end of a properly formed center hole in a lathe mandrel. It will be noticed that the edges of the center hole are well rounded. This form is given to the center hole so that if the mandrel is bruised on the end from any cause, there will be less danger of the center hole being destroyed. If the end of the mandrel were flat, and it should be bruised near the center hole, a slight bump would be raised on one side of the hole that would be sufficient to throw the mandrel slightly out of true. To preserve the center holes further, the mandrel is hardened. The center holes should be made with great care, the angle being 60°, so that they will exactly fit the lathe center. In the best mandrels, the center holes are ground true after hardening. The central portion of the mandrel is carefully ground to size, being made slightly tapered.

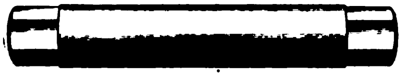


FIG. 41

73. The small end of the mandrel is generally about the exact size, while the large end is from .002 to .003 inch larger, depending on the length of the mandrel and the length of the work to be turned. The taper of mandrels may be from .005 to .01 inch per foot. The large end is distinguished by having the size of the mandrel stamped on it. Mandrels are ground to standard sizes and should fit holes reamed with standard reamers. The necessity of keeping them true may readily be seen when a pulley or similar piece is to be turned true with a part that has been bored and reamed. If the mandrel is untrue, the hole will run untrue as the work revolves. The rim or part of the work being turned will be cut true with the machine, but will not be true with the bore. When the finished pulley is placed on a shaft that runs true, the rim of the wheel will wabble. It may be seen that an untrue mandrel will always produce

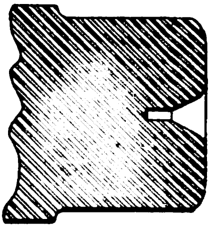


FIG. 42

untrue work and lead to a great deal of trouble. Mandrels may become untrue from the wear of the center holes, and from their being sprung when driven into the work, or by taking too heavy a cut on the work for which they are used.

74. **Care of Centers of Mandrels.**—When the mandrel is placed on centers, the dead-center hole should be well oiled, and the center run carefully into the hole. It is so adjusted that the mandrel will turn freely between centers without lost motion. If the work or the mandrel heats, the pressure due to the expansion will force the oil out of the center hole, causing the center to heat and squeak. At the first suggestion of squeaking, the lathe should be stopped, the center slacked off, well oiled, and readjusted to working conditions.

75. **Putting Mandrels in Work.**—When a mandrel is put in a piece of work, it is usually driven in. The hole and the mandrel are coated with oil, to keep the surfaces from cutting, and, while the work is well supported on the driving block, the mandrel is driven in with a mallet or soft-faced hammer. Hard-faced hammers should never be used for driving mandrels. Babbitt or rawhide-faced hammers are the best. If the work is small, much driving is unnecessary. If the pieces fit well, it will take but little pressure to force the mandrel into the work sufficiently to keep it from slipping. The practice of some workmen of driving a mandrel as long as it can be moved is bad.

76. When driving a mandrel, care should be taken to strike fair blows on the end, as untrue blows are liable to spring it. Mandrels fit best when driven in from the large end of the hole in the work. When roughing cuts are to be taken, however, the mandrel is sometimes driven in from the small end of the hole, as this stretches the small end, and makes a more nearly parallel hole. The finishing is best done with the mandrel driven in from the large end of the hole.

77. **Mandrel Press.**—A far better way of putting mandrels in the work is by the use of a mandrel press. Fig. 43 shows a style of press used for this purpose. It consists of a

heavy cast-iron frame, to which is fitted a plunger *a* that is operated by the hand lever *b*. When a mandrel is to be pressed into a piece of work, the work and the mandrel are brought under the plunger so that the mandrel may be pressed in with a direct, uniform load. These presses are much more convenient for putting in mandrels than the method of driving. Sometimes a mandrel may be sprung by driving it into a crooked hole, if the hole is long and the mandrel slender.

After a mandrel is driven into the work with a soft-faced hammer, the center hole should be carefully cleaned before the work is put between the lathe centers. Dirt in the center holes of a mandrel has the same result in making work untrue as untrue lathe centers.

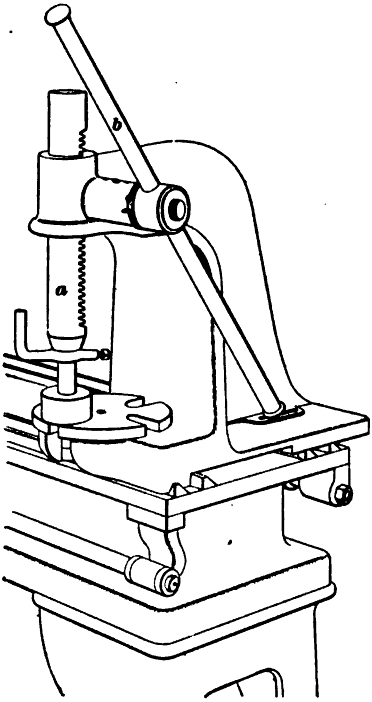


FIG. 43

78. Heavy Cuts on Light Mandrels.—Very often a mandrel is sprung by taking too heavy a cut. This is particularly true if the work is large. For small work, the mandrel will have sufficient friction in the work to drive it so that a dog may be put on the mandrel; but if the work is large and the bore is small, the mandrel will not have sufficient friction to drive it. The mandrel can then be used only to support the work, while the driving should be done by a pin or a stud on the face plate. When the work is thus driven, it is possible to take heavy cuts; but if a deep, heavy cut is taken on the outside of a large piece supported on a small mandrel, the side thrust of the tool will act with such a leverage on the work that it will spring the mandrel. Light cuts, therefore, must be taken. When cutting close to a mandrel with a side tool, as is the case when facing hubs or similar work, care should be taken not to cut into the mandrel. The mandrel may be hardened, but it is not harder than the tool point.

79. Cast-Iron Solid Mandrels.—When solid mandrels of large size are to be used, they are sometimes made of cast iron. The ends of such a mandrel are drilled, and steel plugs are fitted for the center holes. The plugs are hardened after the center holes are correctly made, and are driven or screwed into the cast-iron body. When cast-iron boring bars are made, it is better to use hardened-steel center plugs.

EXPANDING MANDRELS

80. Advantages of Expanding Mandrels.—Although the hardened solid steel mandrel is the best form, some inconveniences arise from its exclusive use. In order to be prepared for all sizes of work, a very large stock of mandrels would be necessary. This leads to inconvenience in some shops, while in other shops it is beneficial. Shops doing a great variety of work, where all sizes of holes are bored, demand a mandrel that can be adjusted to slight differences of diameter. Shops that are making a particular line of work, where many pieces are turned to the same size, are benefited by using the solid mandrel; *first*, because it is more accurate in itself; and, *second*, it acts as a second check-gauge on the work. If a piece that has been bored too large gets into the lot, it cannot be finished, since the mandrel will not hold the work. When the cost of keeping a lot of mandrels up to a standard size is considered, the type of mandrel that will expand within certain limits and fit all sizes of holes within these limits is much cheaper than a great stock of solid mandrels.

81. Types.—One type of expanding mandrel is shown in Fig. 44. It consists of a tapered part *a* that fits into a tapered split bushing *b*. The bushing is ground round and parallel on the outside. As the tapered mandrel is driven into the work and the bushing, the latter expands, thus filling the hole. The method of splitting the bushing as here shown allows it to spring and expand evenly within quite a wide range of limits.

82. Another form of expanding mandrel is shown in Fig. 45. It consists of a steel mandrel that has been centered with the same care found necessary in solid mandrels. Four rectangular grooves are cut along its sides, these grooves being cut deeper at one end than at the other. A sleeve *s* fits loosely over the mandrel, and has slots cut in its sides, which come opposite the grooves cut in the mandrel. A hardened-steel jaw slides loosely in each groove and slot. As the sleeve moves along the mandrel, it carries the jaws with it, and, because of the varying depths of the slots, the jaws are moved in or out, according to the direction in which the sleeve is moving on the arbor. With this type of mandrel, different sets of jaws of different heights may be used, which will give it a range for different sizes of holes. When the work is thick enough to be stiff, so that it cannot be sprung, these mandrels are very convenient; but there is danger of springing the work, due to the outward pressure of the four jaws.

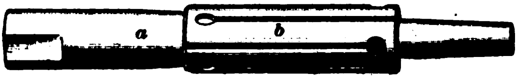


FIG. 44

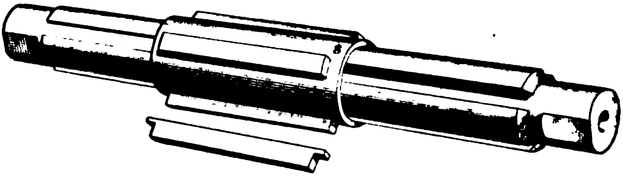


FIG. 45

83. Cone Mandrels.—For some classes of work, a cone mandrel, as shown in Fig. 46, is used. It consists of the central part *a*, to which are fitted two cone-shaped pieces *c*.

One piece is held from sliding along the mandrel by the shoulder *s*. The work is placed between the cones, and the second cone is tightened against the work *w* by the nut *d*. The cones are kept from turning on the mandrel by keys. This is a very convenient way of holding work that does not require great accuracy in being turned.

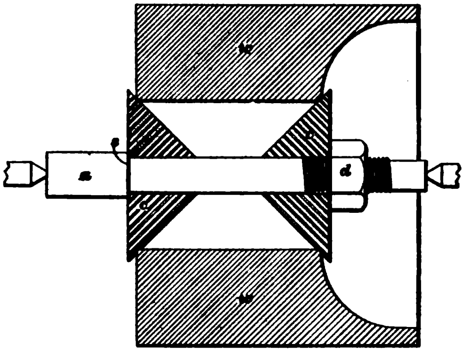


Fig. 46

84. **Special Expanding Mandrel.**—Another form of mandrel for carrying bored or cored work that is being turned and faced is shown in Fig. 47. A heavy bar is drilled and tapped so that screws may be put in square with the bar, as shown at *s*. The circles around the bar in which the screws are placed are at such a point that the screws come near each end of the work. The work is adjusted and held in place by

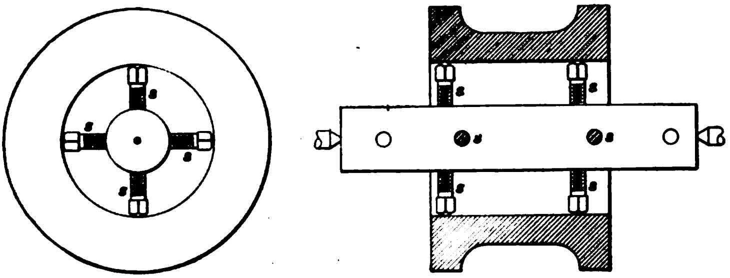


Fig. 47

unscrewing the screws from the bar, thus bringing the pressure on the heads of the screws.

85. Center Spiders.—Large and long pipes and other hollow work may be held and centered by the use of the center spiders shown in Fig. 48. The center spider consists of a cast-iron body *a* having three or more arms *b*, into each of which is screwed radially a screw *c* with a pointed head. Each body or spider has a center hole, either drilled and reamed in the body, or made in a steel piece *d* that is hardened and driven into the body. A center spider is placed in each end of the hole, and so adjusted by the screws that the work runs true on the outside for turning. The four-arm spider is mostly used for large work.

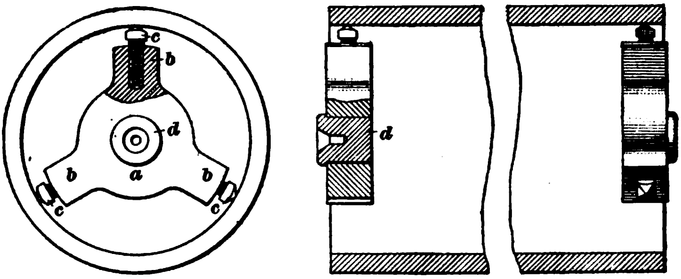


Fig. 48

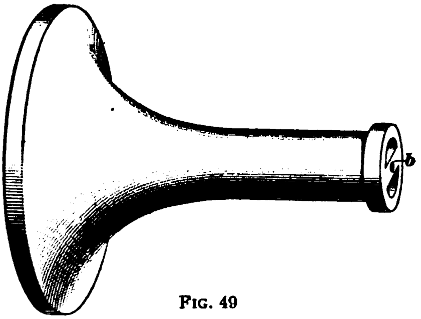


Fig. 49

86. Bridges in Castings.—When heavy cast work has a tapered cored hole that would make it difficult to use the centers just described, it is customary to cast a bridge across the end in which the center hole may be placed. Such a bridge is shown at *b*, Fig. 49. A similar bridge should be cast at the other end of the work. After the turning is done, these bridges can easily be cut out, if so desired. It is usually better to retain them, as their removal is liable to spring the casting.

NUT MANDRELS

87. After a nut is tapped, it is still further finished by facing so that it will be true with the thread. To do this, the nut is usually screwed on a mandrel that has been threaded up to a shoulder. Such a mandrel is shown in section in Fig. 50 with the nut in place. It will be seen that if the nut has not been tapped squarely, and if it fits loosely on the mandrel, it will first come against the shoulder at one side, as at the point *a*. As soon as this point touches, the nut will be rocked on the thread so that the axis of the nut thread will not be parallel to the axis of the mandrel. If the nut should be faced while in this position, the face would not be true with the tapped thread.

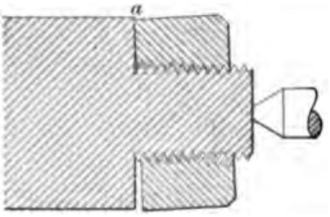


FIG. 50

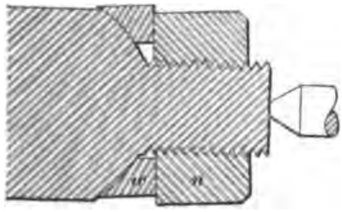


FIG. 51

88. To overcome this difficulty, some sort of equalizing washer must be put between the shoulder of the mandrel and the nut, so that the nut cannot be thrown out of line, but will be held back squarely against the threads. Such a device is shown in section in Fig. 51. The shoulder of the mandrel is rounded to a spherical shape, and the equalizing washer is concaved to fit the round end of the mandrel. This makes a joint similar to a ball-and-socket joint. When the nut *n* is screwed against the washer *w*, and it bears heavier on one side than the other, the washer at once rocks on the rounded end of the mandrel, and adjusts itself to the face of

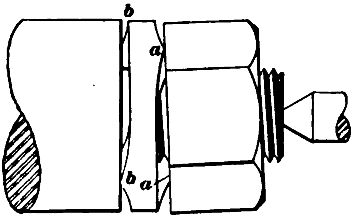


FIG. 52

the nut. Sometimes an equalizing washer, as shown in Fig. 52, is used. The shoulder of the mandrel in this case is squared. On one face of the washer are two projecting points *a* diametrically opposite each other. On the other face of the washer are two other points *b* diametrically opposite, but quartering with those on the first side. When the nut is screwed against the washer thus supported, it is free to rock in any direction, with the result that it centers itself with its threads, and not with the face of the mandrel.

LATHE WORK

(PART 2)

LATHE TOOLS

THEORY OF CUTTING TOOLS

CUTTING PROPERTIES OF TOOLS

1. Requirements of Cutting Tool.—The **cutting tool** used on a lathe is the part that cuts away the metal that must be removed to bring the piece to the desired size and shape. The tool may be forged from a bar; or it may consist of a blade fixed in a holder; or it may be a drill, a reamer, a tap, or some other special tool. The forged tool, which is the most common, is made from bar steel of a size corresponding to that of the lathe on which it is to be used. The bar should be large enough to work with the least amount of vibration, and so that the heat caused by the cutting will be conducted away quickly, even if a lubricant is not used. The cutting edge of the tool must be sharp enough to separate the chip from the work by the use of the least amount of power; but it must also be strong enough to cut for a reasonable length of time without being reground.

2. Theory of Cutting Tools Applied to Hand Tools. In discussing a cutting tool from a theoretical standpoint, attention will first be given to that part known as the **cutting wedge,** which enters the work and severs or removes a part known as the **shaving.**

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The cutting qualities of a tool are governed largely by the shape of the cutting point or cutting edge. The first principles can best be understood by considering the action of a chisel when cutting a block of wood. If a chisel is placed in the center of a block, as shown in Fig. 1, and pressure is applied endwise as indicated by the arrow, the chisel will be forced into the block, bending each side out equally until the block splits. The force required to push the tool into the work will depend on the strength of the block and on the angle *a* of the cutting wedge. If there are two blocks, as in (*a*) and (*b*), of the same strength, it can easily be seen that more power is required to force the blunt wedge *b* into the work than the thinner wedge *a*.

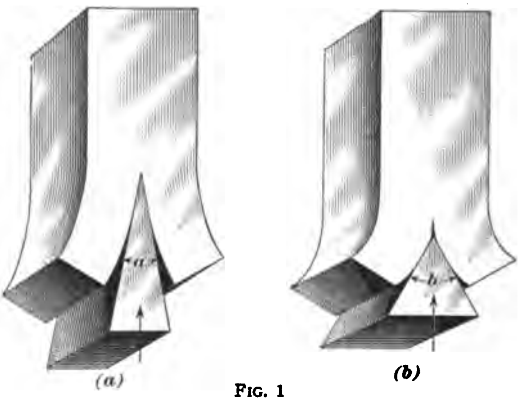
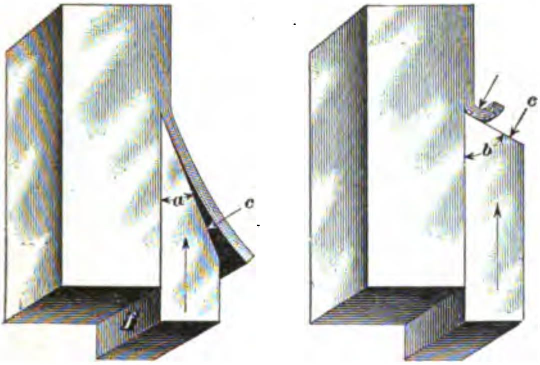


FIG. 1

3. In Fig. 2 (*a*) is shown a chisel cutting a block. The edge of the chisel is ground to an acute angle *a* the same as the wedge in Fig. 1 (*a*). Fig. 2 (*b*) represents a similar block being similarly cut with a tool ground with a blunt cutting edge, the cutting angle *b* being equal to the angle of the wedge *b*, Fig. 1 (*b*). In estimating the force necessary to push each of the tools along its cut, it will be seen that the blunt tool will require the greater force, for the same reason that the blunt wedge, Fig. 1 (*b*), required the greater force to push it into the block. In Fig. 2 (*a*) the shaving is forced from the block, and slightly bent away; but in (*b*) the shaving is very much bent and broken. This bending and breaking of the shaving at the time of severing it from the block absorbs an extra amount of power.

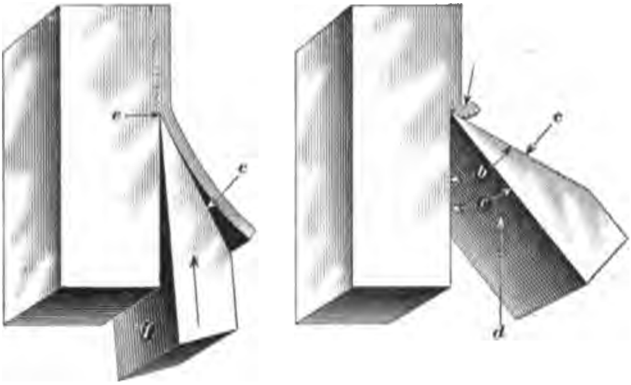
4. The direction of the force required to turn the shaving is represented graphically by drawing a line at right angles to the cutting face of the tool. In Fig. 2 (*a*) the pressure on the face of the tool is square with the beveled face, or in the direction of the arrow *c*. The intensity of the pressure varies with the thickness of the shaving. This force tends to hold the tool very close to the work, and, if it were not for the broad, flat face of the tool, it would be pushed deeper into the work. If the angle of the tool is changed, as in Fig. 3 (*a*), so that the straight face *f* of the tool does not touch the work except along its cutting edge *e*, the pressure of the shaving will be sufficient to force the tool into the work so that as the tool moves along it will cut deeper, as indicated by the dotted line.



(*a*) (*b*)

FIG. 2

5. In Fig. 2 (*b*), in which the tool is very blunt, the result of the pressure against the tool is quite different. The direction of the pressure of the shaving is at right angles to the beveled face of the tool, as shown by the arrow *c*. If this force is divided into two forces, one acting against the direction of tool motion, and the other at right angles to it, tending to hold the tool in the cut, the greater force will be exerted against the direction of tool motion, and but little pressure tending to hold the tool against the work. If the tool is made square on the end, as shown in Fig. 4, the force tending to hold the tool against the cut will be entirely eliminated, and the cutting action will be changed from a shaving to a scraping action. In these hand tools, which are free to move in their natural directions, governed by the angles of the faces, it will be noticed that the tool is guided by one of its cutting faces sliding on the heavier part of the work and that the other cutting face bends the shaving out of its place.



(a) (b)

FIG. 3

6. Theory of Cutting Tools Applied to Machine Tools.—It has been shown that, of the two tools illustrated in Fig. 2, less power is required to move the tool with the sharp angle *a* than is necessary to force the tool with the blunt cutting edge *b*. This was true when the tools were free to follow in their natural courses. When the tool is rigidly held in some position, and forced to cut along some other line than its natural one, the condition becomes very much changed, and the power required varies accordingly. Suppose that the tool with the sharp cutting angle shown in Fig. 2 (*a*) is presented to the work as shown in Fig. 3 (*b*), so that its cutting face makes the same angle *b* as the cutting face of the tool shown in Fig. 2 (*b*). If this tool is held rigidly at this angle and forced along the work in the direction of the arrow *d*, it will be found that for equal depths of cuts the same amount of power will be required to move it as in the case of the tool shown in Fig. 2 (*b*). From this it may be seen that if a tool is clamped in any position and moved along a certain line of motion, the cutting action depends as much on the position it holds relative to the work as on its exact shape.

7. Angle of Clearance.—The tool shown in Fig. 2 (*b*) is much stronger than that shown in Fig. 3 (*b*) because of the greater support given to the cutting edge. In Fig. 3 (*b*) the cutting edge has very little backing or support, and it would break at once. When this tool is held and moved as shown in Fig. 2 (*a*), it is in its strongest position. When it is moved so that its face makes an angle with the work, its strength begins to decrease as the angle *c*, Fig. 3 (*b*), increases. This angle *c* which the back face of the tool makes with the work is called the angle of clearance.

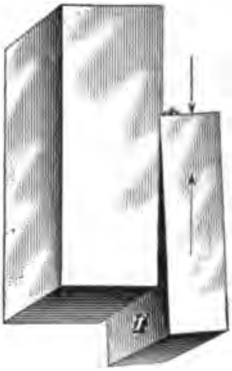


FIG. 4

8. Angle of Keenness.—If the tool in Fig. 2 (*a*), which is held in its strongest position, is compared with the tool shown in (*b*), it will be seen that the latter is the stronger. This strength is due to the support given to the cutting edge because of its bluntness. The angle between the cutting faces of a tool, as the angle *a* or *b*, Fig. 2, is called the angle of keenness of the tool. The strength of a cutting tool, therefore, depends on the angle of clearance and the angle of keenness. The angle of keenness of a tool should vary with the degree of hardness of the material to be cut. For turning soft woods, the turning tool is ground very keen, or so that the cutting faces make a very thin or acute angle with each other. In turning metals, the cutting edges are made less keen, depending on the hardness of the metal. In some cases, as in turning chilled cast-iron rolls, the angle formed by the cutting edges is nearly 90°.

9. **Angle of Rake.**—A diamond point is shown in Fig. 5, with lines drawn to indicate its angles of rake and keenness. AB is drawn through the point O, parallel to the base of the tool. CD is perpendicular to AB at O. EF is parallel to the top face of the tool at O. HK is parallel to the front edge of the tool at O. The angle AOE represents the angle of top front rake of the tool, the angle DOH represents the angle of front rake, and the angle EOH represents the angle of keenness. These angles as here described refer to the tool alone. When the tool is clamped in the tool post, and presented to the work to take a cut, these angles assume a new relation to each other, and the cutting qualities of the tool depend on these new relations.

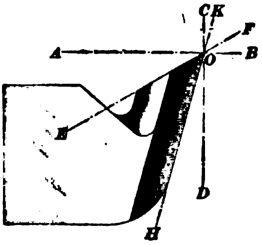


FIG. 5

10. A diamond point correctly set for turning a cylindrical piece is shown in Fig. 6. To measure properly the angles of the tool thus set, draw the line AB from the center of the work through the point of the tool, and draw CD perpendicular to AB at O. Draw EF parallel to the top face of the tool through the point O, and draw HK parallel to the edge of the tool. The angle AOE is then the angle of top rake of the tool, the angle EOH the angle of keenness, and the angle DOH the angle of clearance. The difference in drawing the lines in Figs. 5 and 6 begins with drawing the line AB. After this line is properly drawn, the other lines follow in the same course.

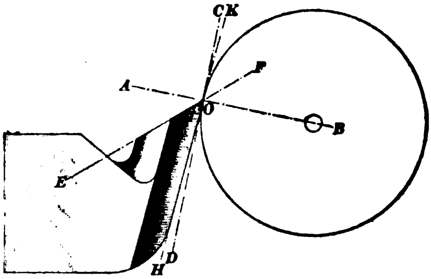


FIG. 6

When the height of the tool is changed, the angles of top rake and clearance are changed; but the angle of keenness depends on the shape of the tool, and is not affected by the setting. When the top face of the tool is ground sloping from one side, as shown in Fig. 7, the tool has top side rake. The angle of top side rake is measured by drawing $A\,B$ parallel to the base of the tool through the point S, and $E\,F$ parallel to the top face of the tool through the point S; then the angle $A\,S\,E$ is the angle of top side rake.

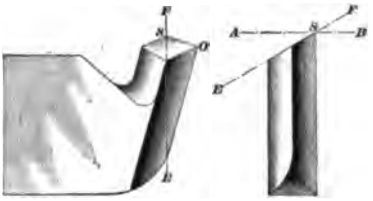


FIG. 7

CONDITIONS GOVERNING SHAPE OF TOOL

11. Conditions Influencing Angles.—The angles of rake, clearance, and keenness of the tool depend on the kind of metal to be cut, the hardness of the metal, and the kind of cut, whether roughing or finishing. Then, even after the several angles of the tool are fixed, the manner in which the tool is set when it is fed up to the work may alter the effect of the angles. For this reason, the term *effective angle* will be used frequently in connection with the angles of tools when taken in relation to the work for which they are set. As an example, refer to Fig. 6. The angle of keenness of the tool is $E\,O\,H$, but when the tool is set, the *effective* angle of keenness is $E\,O\,D$, which is equal to the sum of the angle of keenness $E\,O\,H$ and the angle of clearance $D\,O\,H$. In like manner, the actual angles of rake and clearance may be affected by the setting of the tool.

12. Effect of Kind of Metal.—In general, it may be stated that for soft material, such as mild steel, the angles are keener than for hard material, such as chilled cast iron, and for some materials that have a tendency to draw the tool in, as brass or copper, the angles may be made very blunt indeed; in fact, negative rake is often given to them.

13. Effect of Hardness of Metal.—The angle of keenness varies with the hardness of the material. Tools for cutting soft steel should be ground with sufficient keenness to enable them to turn long, curly shavings. When the shavings come off in large curls, and are very strong, it indicates that the tool is properly ground and set in the machine. When the shavings come from the work broken in small pieces, it indicates that the tool is laboring because of incorrect setting in the machine or incorrect grinding. A word of caution should be given here to those who, for the first time, see a tool, properly ground and set, roll off a beautifully curled shaving. Never attempt to remove the shaving from the work by pulling or jerking it. A good steel shaving is hot and very strong, and its edges are as keen as a knife. The shaving may slip through the hand, cutting the flesh in a most painful way. To remove the shaving from the cut, throw out the feed and the tool will cut off the shaving.

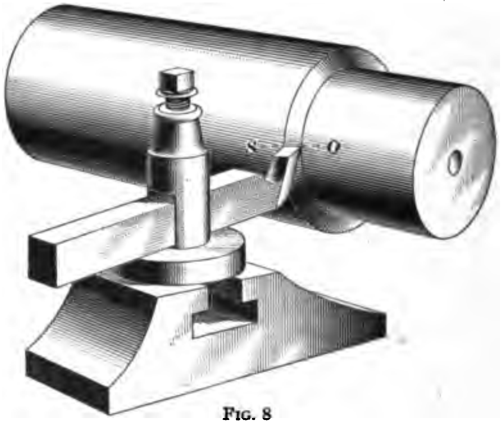


FIG. 8

14. Rake for Roughing and Finishing Cuts.—The angle of top rake depends on the nature of the cut, whether roughing or finishing. Fig. 8 shows a piece of work with the tool set to take a roughing cut, which is usually a heavy cut. Here the cutting is done along the left-hand edge *O S* of the tool, the point *O* doing a very small part of the work.

This tool should be ground to give keenness all along the cutting edge *O S*, which is done by giving the tool top side rake.

When the tool is used for a finishing cut, the cut is very light, and most of the cutting is done with the point of the tool *O*. In this case, top front rake, as shown in Fig. 6, should be given. Top side rake and top front rake are governed also by the rate of feed used, a tool with side rake using less feed than one with front rake.

15. A case is shown in Fig. 9, in which the feed is coarse and the tool point broad, so that the rate of feed per revolution of the work is greater than the depth of the cut. In such a case, the top front rake should exceed the top side rake. When the feed is fine compared with the depth of the cut, the top side rake should be the greater.

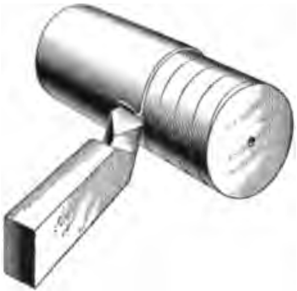


FIG. 9

16. Effect of Feed on Shape of Tool.—The shape and width of the point of a tool depend on the feed used, and this depends on the nature of the work. In finishing small rods, shafts, or spindles that should be very true, the roughing cut is made deep with as coarse feed as the work and the tool will stand, and the finishing cut is light, and the feed comparatively fine. The fine feed is allowable because it cuts the work very true, and on small work the tool will quickly feed over it and remain sharp up to the end of the cut. On large work, the method is different. Deep, heavy roughing cuts are taken, as before; but the finishing cut is taken with a tool that has a broad, flat point and a very coarse feed. When the work is heavy, this form of tool can be used and will turn comparatively true; but on slender work a broad-nosed tool could not be used at all. A broad-nosed tool should be used for finishing, whenever possible. It saves much time because of the coarse feed that can be used, and the tool will usually remain sharp until the end of the cut, unless the cut is very long.

17. Change of Front Top Rake to Side Top Rake. The angle of top rake may be changed effectively from front top rake to side top rake by swinging the tool from its setting square with the work, and clamping it so that it cuts ahead of the tool post, thus changing the angle of the tool with the work. Fig. 10 (*a*) shows a broad-nosed finishing tool ground with top front rake and set square with the work. It may be changed to a very efficient roughing tool resembling a tool with top side rake, by swinging it so that it cuts ahead of the tool post in the position shown in (*b*).

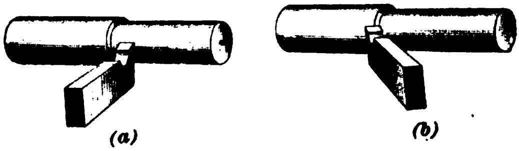


Fig. 10

18. Special care should be taken when using a tool set ahead of the tool post; for if it becomes loose in the tool post it will swing into the work and may do great damage. It is always best to have the tool post in advance of the point at which the tool is cutting, so that the tool will swing away from the work if it becomes loose. When working on expensive material, the tool should never be set so it can swing into the work; but a regular roughing tool should be employed.

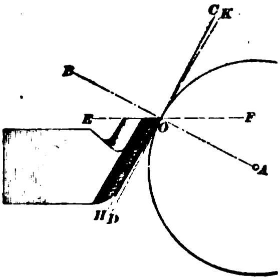


Fig. 11

19. Effect of Height of Tool on Angles of Rake and Clearance. It is well to study the effect of setting the tool at different heights, so that any difficulty from this cause may be recognized and remedied. Fig. 11 shows a tool ground flat on its top face so that it is without top rake. By applying this tool at its highest possible cutting position, and drawing the lines as in Fig. 5, there is an effective angle of top rake *EOB*, Fig. 11, and an effective clearance angle *HOD*. Suppose this same tool is next lowered to the position shown in Fig. 12, the point of the tool being level with the axis of the work. By drawing the lines as before, the line *A B* coincides with the line *E F*, so that the tool has no top rake, and the angle of clearance is *H O D*. At this point, the cutting action changes from a shaving to a scraping action, which can never admit of a deep cut. Next, suppose the tool to be set below the center, as shown in Fig. 13. By drawing the lines as before, *A B* passes into the tool below the line *E F*. In this position, the tool has a negative angle of top rake *E O B*, and will do little more than scrape the work.

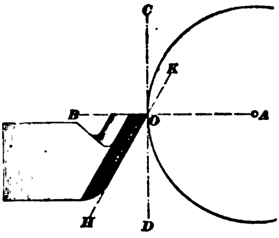


FIG. 12

20. Effect of Height of Tool on Its Strength.—The effect of the position of a tool on its strength can also be seen from Figs. 11 to 13. In Fig. 11 the angle of clearance *D O H* is very small, and the cutting edge is well supported; consequently, the tool is in its strongest position. In Fig. 13 the angle of clearance *D O H* is great, and it is easy to see that the cutting edge cannot endure much pressure. From this it will be seen that a tool is strongest when set as high as possible on the work.

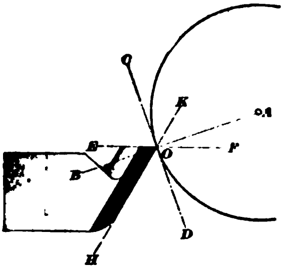


FIG. 13

21. Clearance Angle of Side Tools.—Side tools usually work on flat surfaces, and are originally made so that the cutting edge is straight. In consequence, a constant angle of 12° side rake is usually given. The side tool is often used as a forming tool by setting the cutting edge to the required angle of some surface, as the end of a small shaft to be squared up, or an edge or face of a bevel gear, and making the whole cut at one setting.

22. Shape and Setting of Tools for Brass Work. The theory of the shapes of tools and the methods of applying them to the work, as just described, are not always sustained when applied to tools for brass. This is due largely to the peculiar nature of brass found in its toughness and its flexibility. These qualities tend to cause a tool to spring into the work and the work to spring over the tool in such a way as to make very untrue cuts. If the work and the tool could be held with sufficient stiffness to avoid all danger of springing, the tool could be ground with more keenness than is allowable for iron or steel. In practice, it is found that good results are obtained with a round-nosed tool ground without top rake or side rake, as shown in Fig. 14 (*a*), and set with its top face level with the center of the work. Sometimes the tool is made with negative top rake, as in (*b*), the other angles remaining as in (*a*).

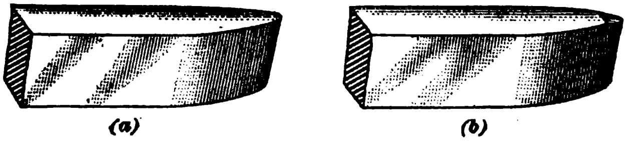

(*a*) (*b*)

FIG. 14

FORMS OF CUTTING TOOLS

FORGED TURNING TOOLS

23. Steels Used for Cutting Tools.—The steels used for lathe tools are known as *carbon*, *high-speed*, and *semihigh-speed steels*.

24. Carbon tool steel is steel that contains from .75 to 1.5 per cent. of carbon. It is more easily forged than either of the others and can be made of any desired degree of hardness. If, when forging, this steel is heated higher than a bright red, the carbon will be burned out and the steel ruined. When grinding or using, the cutting edge of the tool will be softened if heated to 550° F., as shown by the characteristic bluing of the steel. When the temper is drawn to a blue color, the edge will wear away and it will be necessary to harden and temper the tool again. This sensitiveness to heat limits the cutting speed of carbon-steel tools.

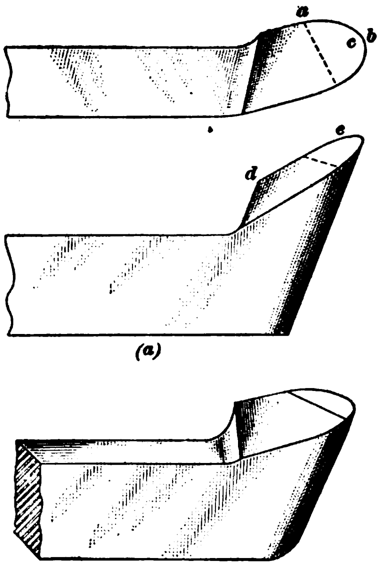
25. **High-speed steel** contains tungsten, or molybdenum and chromium, in addition to the iron and carbon. It is harder to forge than either carbon or semihigh-speed steel, and must be heated to about 2,200° F., a white heat, for hardening. The tools are then cooled in a blast of air, an oil bath, or a lead bath. High-speed steel tools treated in this way will cut about four times the quantity of the same quality of metal in a given time as will carbon-steel tools. The great advantage of high-speed steel tools over all others lies in their property of *red-hardness;* that is, when heated to a red heat the tools remain hard. Because of this fact, much higher cutting speeds can be obtained by their use.

26. **Semihigh-speed steels** contain the same elements as high-speed steels; but the percentage of tungsten or of molybdenum and chromium used is not so high. When hardening, the tools are heated to a bright red and then laid down to cool in the air, cooled in an air blast, or quenched in oil. Those semihigh-speed steels that contain very little tungsten or molybdenum and chromium are sometimes cooled by quenching in water. Semihigh-speed-steel tools have greater endurance and work at higher speeds than carbon-steel tools; but they have less endurance and work at lower speeds than do high-speed-steel tools. They do not have the property of red-hardness to the same extent, but have some of it.

27. The lathes on which carbon-steel tools are used are not well-suited for obtaining the best results with high-speed-steel tools. They are not sufficiently powerful for the heavy cuts at the allowable speed that may be taken with high-speed tools, and they are not massive enough to absorb the vibrations set up by the heavy cuts. The lathe that works to the best advantage must be built with large spindles and bearings, and have plenty of driving power. It must also have its parts so designed that there will be metal enough used and correctly distributed to do the work with the least vibration.

High-speed-steel lathe tools may be used for all classes of work; but they find their greatest service in the rapid removal of stock from iron and steel forgings or castings, or bars which are turned down without first being forged approximately to the desired size and form.

28. Shapes of Forged Roughing Tools.—In forging high-speed steel, it should be worked at a temperature of 1,800° or 1,900° F., and it is very difficult to draw or bend it into a diamond point or other similar shape. It is usually heated, bent, and cut with a hot chisel approximately to shape, after forging or bending, and is finally shaped on the grinding wheel. Fig. 15 (*a*) shows an elevation and a plan of a roughing tool as forged from this steel. The left side *a b* has been curved to make the cutting edge, the point *c* bent up to give top rake along the line *d e* and the heel dressed so that little grinding will be required on the front end of the tool. When the tool is ground, it appears as shown in (*b*). This tool will be seen to possess the same cutting angles as shown in the diamond point, although it is quite different in general appearance. As the point *c* is at one side, its cutting edge is entirely along the curved left edge *a b*. It is thus designated as a *right-hand tool*, as contrasted with one whose cutting edge is on the opposite, or right-hand side, and which is therefore known as a *left-hand tool*.



(*a*)

(*b*)

FIG. 15

29. Proper Form of Round-Nosed Tools.—For some kinds of work, a round-nosed tool, shown in Fig. 16, is used; this is ground round on the point and flat on the top. If it is to be given top rake, it should be forged so that the top rake can be ground easily. Fig. 17 shows how such a tool should be forged. This style of forging allows the top face of the tool to be ground, and the angles kept unchanged.

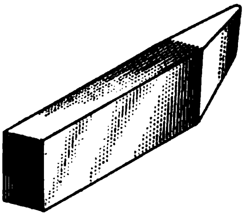


FIG. 16

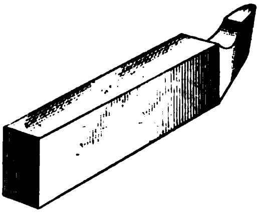


FIG. 17

A round-nosed tool is desirable for turning the piece shown in Fig. 18, as it can be set to cut the round part *a* and the flat face *b* without resetting.

30. The ordinary round-nosed tool with the point in the center, and ground without top front rake, may be used to cut in either direction. If ground with top side rake, to cut toward the live center, it is called a right-hand tool; if ground sloping the other way, it is called a left-hand tool. When heavy cuts and great strength are required, the outline of the cutting edge is curved and the point is considerably rounded.

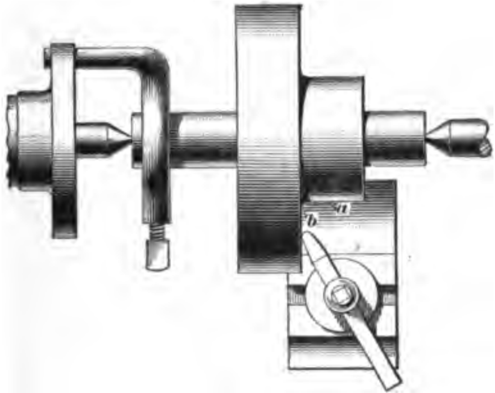


FIG. 18

This applies particularly to heavy work. Fig. 19 shows a form of round nose used for some kinds of heavy work. Fig. 20 shows a form of broad-nosed tool that may be used for finishing when coarse feeds are permissible.

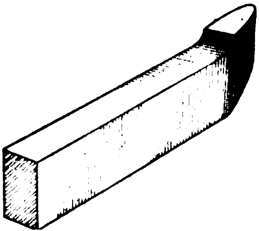


Fig. 19

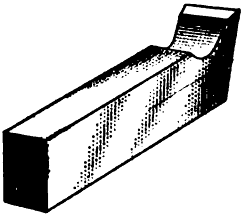


Fig. 20

TOOL HOLDERS FOR TURNING TOOLS

31. Advantage and Disadvantages.—The expense of keeping up a stock of tools forged from the bar, whether of carbon steel or of alloy steel, is great, and this fact has led to the devising of many forms of holders employing small blades of steel to do the cutting. Holders are made of the same size as the shank of the ordinary forged tool. They make a very great saving in the cost of the steel used, as one holder will be sufficient for a great variety of shapes of cutting points, tools, or blades. The blades may be of the very finest and most expensive quality of steel, and still cost far less than the forged tool.

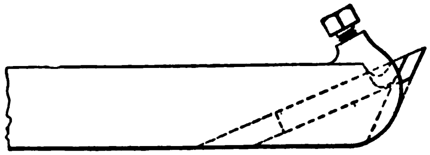


Fig. 21

The objection to inserted-blade tools or tool holders is that it is difficult to find a means of clamping the small blade in the holder so that it will have the same rigidity as the forged tool. The holders soon wear, allowing the blades to spring. In many cases this is caused by using too small a holder. If heavy holders and comparatively large blades are used, the trouble will be partly avoided.

32. Holders for Diamond Points.—Two styles of tool holders for diamond points are shown in Figs. 21 and 22. The similarity of the point of the tool shown in Fig. 22 to the regular forged diamond point is readily seen. In Fig. 21 the tool shown has the outline of a diamond point sketched over it in dotted lines, from which it may be seen that the shapes of the cutting edges are identical.

33. Grinding of Diamond-Pointed Inserted-Blade Tools.—The methods of grinding the tools shown in Figs. 21 and 22 are quite different. In Fig. 22 the cutting tool is ground entirely on its top face. The angle of keenness is thus determined, and as the angle of front rake remains unchanged in the tool, it is always set at the same height for a given diameter. In Fig. 21 the angle of top rake of the tool is determined by the angle at which the tool sets in the holder. Grinding should be done entirely along the end of the blade that corresponds to the front face of a diamond point. In this case, to increase the keenness of the tool, it is necessary to grind it away at the heel. It must be remembered, however, that the keenness given the tool by changing its angle of front rake will not change the effective keenness when applied to the work, unless the position of the tool is changed. Grinding away the heel makes it possible to set the point higher on the work. This higher position gives an increased angle of top rake and therefore increases the effective angle of keenness. Other forms of tool holders, similar to these, accomplish the same purpose.

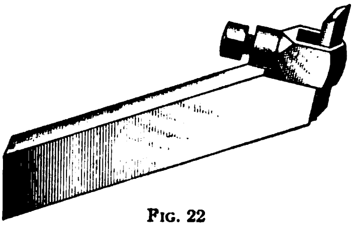


FIG. 22

34. Heavy Inserted-Blade Tool Holder.—The tool holder and tool shown in Fig. 23 are designed for heavy cuts and high speed. The form and angles of the cutter are the same as those of a forged roughing tool. The cutter is to be ground only on the top face, and can be used until very short. The objection advanced against tool holders in general for heavy work is that, because of lack of proper contact of the tool with the holder, they do not carry off the heat generated by the chip. The holder shown in Fig. 23 is designed to overcome that trouble.

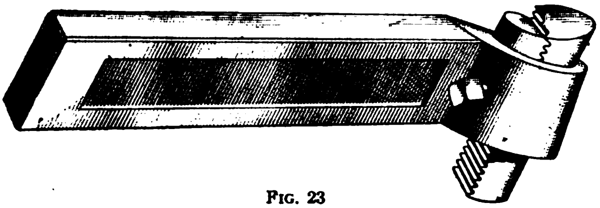


Fig. 23

PARTING TOOL OR CUTTING-OFF TOOL

35. Forged Parting Tool.—A common form of parting tool is shown in Fig. 24 (*a*) and (*b*). It is used for cutting square grooves or notches in work, for cutting square corners, or for cutting off work held in a chuck. The cutting edge of the tool is along the top front line *AB*. The blade is forged and ground so that the cutting edge is the thickest part. Each side of the blade is ground with a slight amount of clearance, as shown by the section *CD*. The tool is not ground with top rake, keenness being given by varying the angle of front rake. When this tool is used for cutting off, it should be set at the same height as the center of the work, and square with the axis.

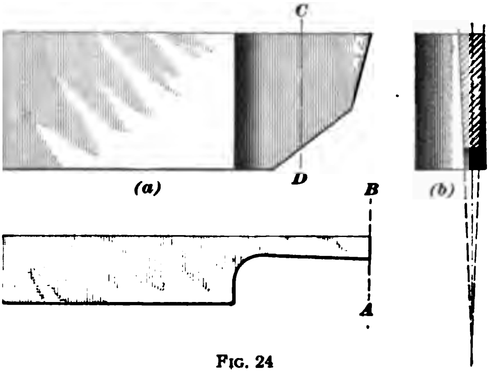


Fig. 24

36. Use of Parting Tool.—A piece of work held between centers should not be cut entirely in two by a parting tool. It may be cut partly in two, after which it should be taken from the lathe and either broken or sawed apart. Fig. 25 shows the tool deep in a cut. Soon the piece will become so reduced in diameter that the pressure due to the feed will bend the work, which, at this small diameter, will open the cut on one side and close it on the other, so that the tool cannot pass through and will become jammed in the cut. This may break the lathe tool, or the lathe center may be broken or torn out of the center hole.

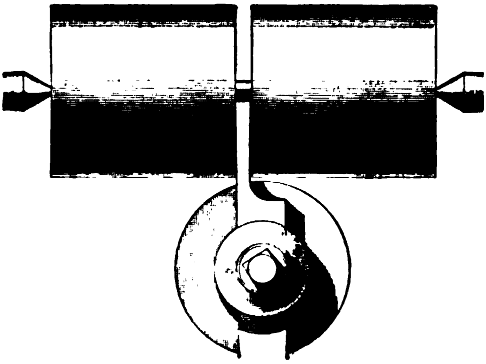


Fig. 25

37. Inserted-Blade Parting Tool.—Inserted-blade tool holders are very successfully used for parting tools. Fig. 26 shows one style of inserted-blade parting tool. The blade is held in the holder by the clamping screw *s*, and is still further secured, when the tool holder is clamped in the tool post, because of the spring of the tool holder. Fig. 27 shows another form of parting tool with inserted blade. The blades for these tools are ground either concave on the side or thinner on the bottom edge, to give clearance. They are made from either high-speed or carbon steel. When the blades are made

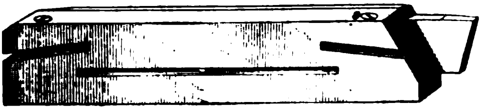


Fig. 26

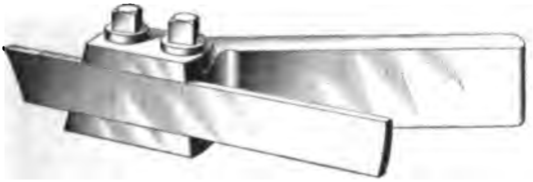


Fig. 27

from carbon steel and hardened, it is customary to draw the temper along the lower edge, which gives the tool toughness, a quality much desired.

SIDE TOOLS

38. The **side tool** is a tool of the form shown in Fig. 28, and is used in squaring up the ends of work held between centers, or for forming shoulders. It may be made either right hand or left hand, so that it can be used on either side of a piece. The form shown in the illustration is a right-hand side tool. The left-hand tool is offset in the opposite direction.

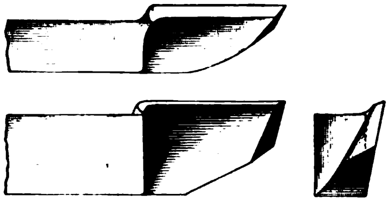


FIG. 28

39. Grinding.—A lathe tool is ground to secure the desired form and shape and to make it sharp. After a tool is once correctly shaped there should be as little grinding as possible, in order that the original shape may not be changed. Much needless grinding wears away the tool. Fig. 29 shows an end view of a correctly shaped side tool and illustrates how it is presented to the work as seen from the back of the lathe. The cutting edge of the tool is at the height of the center of the work, and the face *A B* of the tool is ground flat and at an angle to the line *C D*, which is parallel to the side of the shank. The small angle formed between the lines *A B* and *C D* is the angle of side rake. The top face denoted by the line *E F* is usually

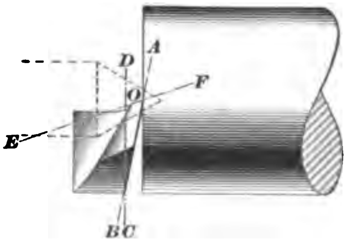


FIG. 29

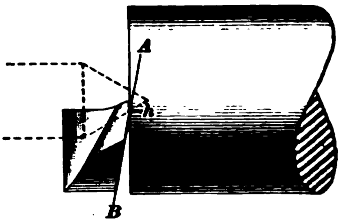


FIG. 30

ground to make an angle with the face *A B* of about 60° for cast iron and 55° for wrought iron or soft steel.

40. In sharpening the tool the most grinding should be done on the top face *E F*, Fig. 29, care being taken to keep the original shape of the tool. Fig. 30 shows how a careless workman may round the face *A B* of the tool in attempting to make the cutting edge sharp, with the result that the tool cannot cut because of the high place *h*, which touches the face of the work first. After a tool is ground on an emery wheel or a grindstone, it should be finished on an oilstone, to give it a keen edge.

BORING TOOLS

41. Working Conditions.—The conditions under which a boring tool must work are most unfavorable for carrying out the principles that naturally lead to good results. The boring tool, because of the long, slim arm required to reach into the bottoms of small holes, lacks that rigidity of cutting edge that is essential in rapid, accurate work.

42. Cutting Angles.—As shown in Fig. 31, the angles of rake and keenness for a boring tool may be defined the same as in a diamond point. The line *A B* is drawn from the axis of the work through the point of the tool, and *E F* is drawn along the top face of the tool through the point *O*. The angle *B O F* represents the angle of top rake. If the tool is raised or lowered in the hole, the angle of top rake will vary, just as in Figs. 11 to 13.

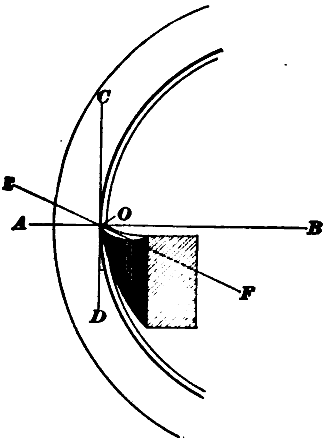


FIG. 31

43. Spring of Boring Tools.—The force necessary to hold the point of the tool up to the cut depends largely on the shape of the point. Fig. 32 (*a*) shows a well-shaped tool for small work. The point is narrow, and has much the same shape as that of a diamond point. The force tending to spring the tool away from the work is in the direction of the arrow, at right angles to the line *A B*. In (*b*) is shown a tool with the point more rounded, with the force tending to spring it away from the work more nearly at right angles to the shank of the tool. In (*c*) is shown a broad-nosed tool with the force acting squarely across its shank. This tool will chatter and spring away from the work so that it will be difficult to do much with it. Single-pointed boring tools should have narrow points, as shown in (*a*), and should be used with moderately fine feeds. Broad-edged boring tools used with coarse feeds are held in boring bars or heads.

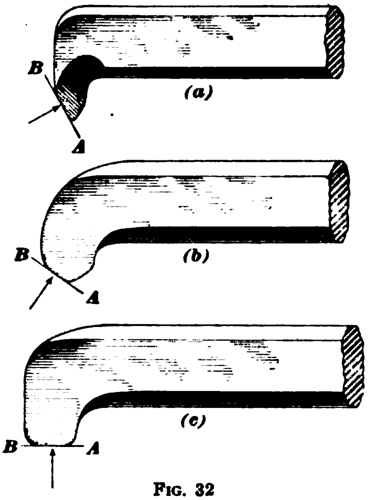


FIG. 32

44. Height of Boring Tool.—The correct height of the boring tool in the work, to give it the strongest and the easiest cutting position, is as much *below* the center as it can be set and still have its cutting point cut. This is for the same reason that the diamond point is set *above* the center of the work. If the tool is long or springy it is not always safe to set it in this low position, for, as it is below the center, if it should catch and spring down, it would spring into the work more deeply and cause trouble. Ordinarily, a boring tool is set level with the center of the work, it having been so ground that when thus set it will have but little clearance.

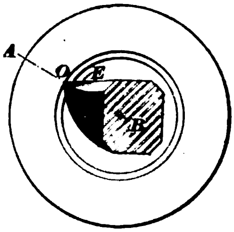


FIG. 33

45. Boring Small Holes.—When the hole is small, the conditions are more unfavorable. Fig. 33 shows a section through work with the tool in place. The tool nearly fills the hole. When a line $A\ B$ is drawn from the center through the point O, it passes into the tool, showing that in this position it has negative top rake. The best that can be done in this case is to grind the top face back from the end edge E, giving the tool a great deal of top side rake.

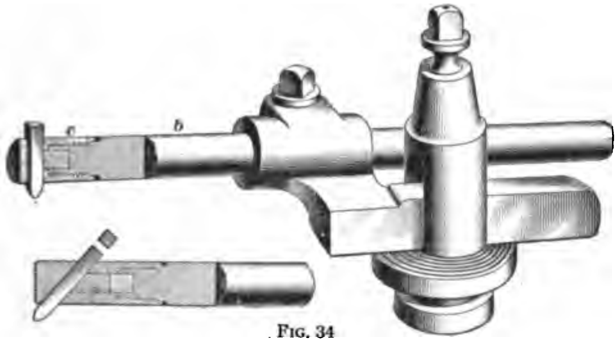


Fig. 34

46. Special Holders for Boring Tools.—For boring tools, special holders with inserted blades are superior to forged tools. Fig. 34 shows a special boring tool that can be held in the tool post of the lathe. The blade is held in the end of the bar b by a cap c, which screws over the end of

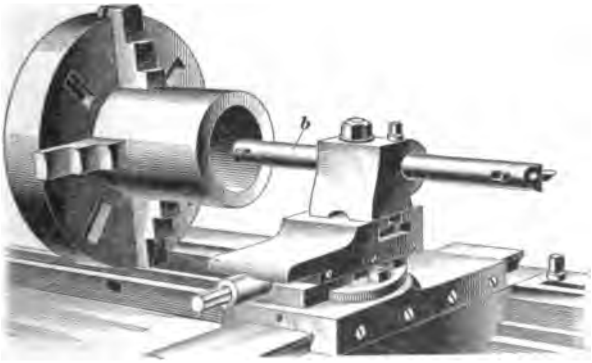


Fig. 35

the bar. The bar *b* can be adjusted in the holder so that it will just pass through the work. Fig. 35 shows another form of boring tool with inserted blade. This form holds the bar *b* very rigidly in a special block bolted on the lathe tool block. A boring-tool holder having many advantages is shown in Fig. 36 (*a*). The shank *a* has a **V** cut in the top to take a boring tool made from round stock of any required length. A clamp *b* on the working end of the holder adds stiffness to the tool when it has been adjusted to the required length to bore to the necessary depth. The tool and holder are clamped rigidly in the tool post *c*. A recessing tool is shown in (*b*), a straight-nosed tool in (*c*), a common boring tool in (*d*), a circular internal threading tool in (*e*), and an internal threading tool in (*f*). These tools are made to fit in the holder shown in (*a*).

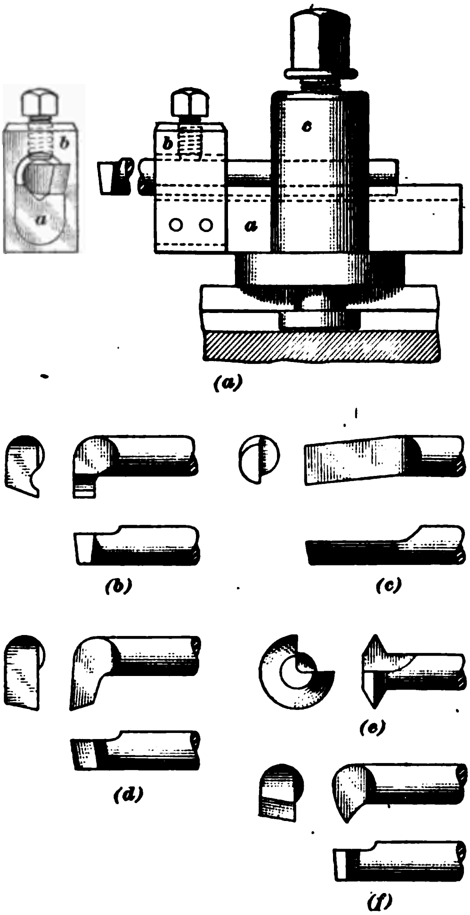


FIG. 36

47. When the holes to be bored are small, a bar that nearly fills the hole may be used. It may be set to project beyond the holder just far enough to pass through the work. The tool is thus given the greatest possible rigidity. Furthermore, because of the low position of the cutting tool, Fig. 37, the cutting action is much better than could be obtained with the forged tool as ordinarily ground. For heavy work, the style of bar shown in Fig. 34 has too much spring; hence the form shown in Fig. 35 should be employed. The lighter bar is very handy for small work. Sometimes the clamping block shown in Fig. 35 is split and secured to the tool block by two bolts. These bolts hold the block together as well as in place, and so secure the bar *b*.

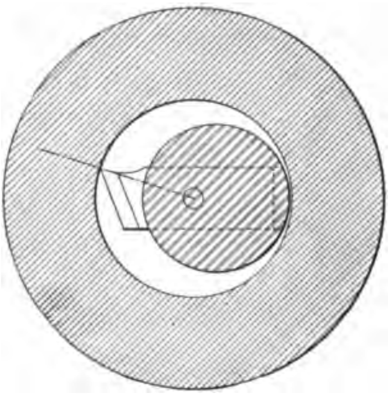


FIG. 37

BENT TOOLS

48. For some kinds of work, the straight tools that have been described cannot be used, and a class of tools known as bent tools becomes necessary. They are classed as right-hand or as left-hand tools, depending on the direction in which they are intended to cut.

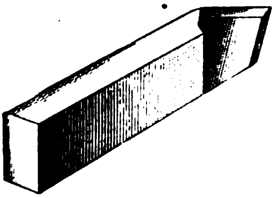


FIG. 38

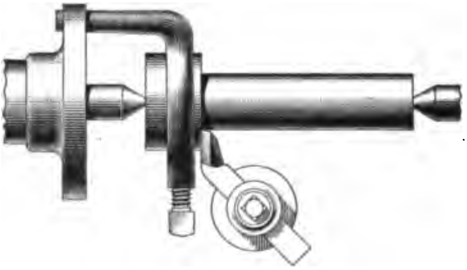


FIG. 39

49. A right-hand bent side tool is shown in Fig. 38. This form of tool is especially desirable when cutting a shoulder that is very close to the lathe dog, as shown in Fig. 39.

50. When it is desired to cut work very close to a shoulder or the jaws of a chuck, a bent parting tool may be used, as shown in Fig. 40. The offset tool holder shown in Fig. 27 is particularly well adapted to this class of work.

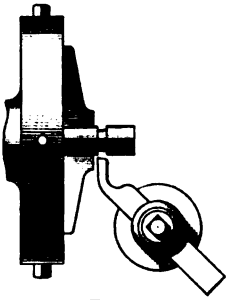


Fig. 40

51. Round-nosed tools may be bent either right or left, to meet certain conditions of work. The right-hand bent round-nosed tool is often used for facing, and it makes a good inside turning or boring tool.

FORMING TOOLS

52. Under favorable conditions, it is possible to use a tool with a very broad cutting edge, 8 inches or more in width. These conditions are: rigidity of the work, rigidity of the tool, and power of the lathe. When a piece is to be finished with a curved or irregular surface, as shown in Fig. 41, special forming tools can be made that save much time, and do much better and more uniform work than can be done by hand. These tools are carefully made so that they have the proper clearance along the line *G H*, Fig. 42, and should be sharpened by grinding entirely on the top face. When used, they should be set at the same height as the center of the work. On wrought iron or steel, plenty of lard oil should be used. Very complicated forms may be produced by the use of forming tools.

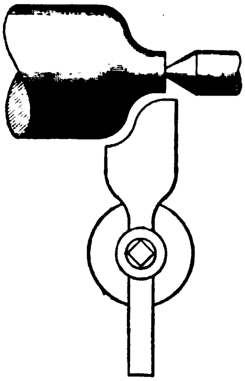


Fig. 41

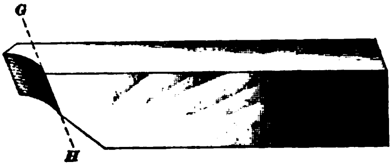


Fig. 42

SPRING TOOLS

53. In most cases, rigidity of work and tool is sought for the purpose of producing the most accurate and the smoothest surfaces. In some cases a special spring tool is used to overcome chattering and roughness of cut that cannot otherwise be avoided.

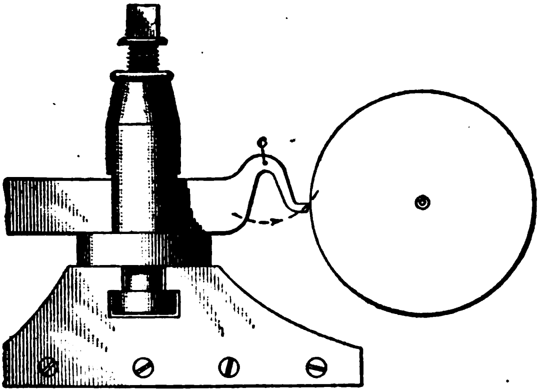


FIG. 43

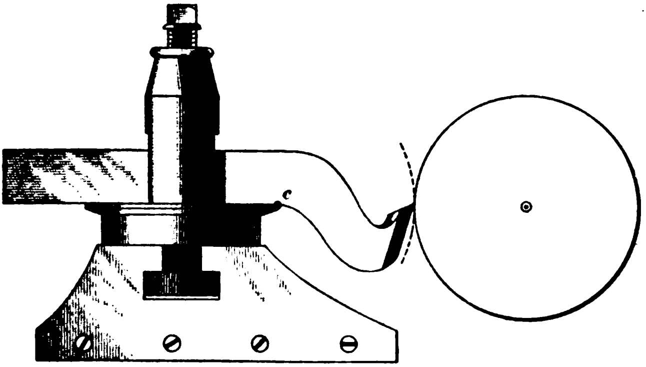


FIG. 44

54. In Fig. 43 is shown a *spring tool*, or *gooseneck tool*, as it is sometimes called, applied to the work. It is set so that its cutting edge is level with the center of the work. Any tendency on the part of the tool or the work to vibrate or chatter is taken up by the narrow springy part of the tool. It will be seen that the gooseneck tool can never dig into the work, because the pressure of the cut is constantly tending to press the edge away from the work in a circle drawn about the center *c*, at the top of the bend.

55. Another form of spring tool is shown in Fig. 44. This form is intended to avoid all danger of springing into the work, and is so set that as the force of the cut bends it down, the point follows the arc of the circle as indicated. The circle is drawn about the point of support of the tool. As the tool springs down, the point will naturally move away from the work, and so prevent digging into the stock.

HAND TOOLS

56. Diamond-Pointed Hand Tool.—Hand tools, as their name implies, are held in the hand while operating on the work. Their cutting action depends on the skill of the workman. Their cutting power, compared with tools held in a slide rest, is very small. Their principal use in metal working is turning and finishing a great variety of work on hand lathes or small bench lathes for working brass, and for finishing curves and pieces of irregular outline. Chief among these tools is the diamond-pointed hand tool. It is a piece of square steel ground with a bevel on the point, as shown in Fig. 45. When this tool is used for rounding a corner, such as the end of a bolt or screw, it rests on one edge *c*, Fig. 46, while the keen edge *A B* does the cutting. The angles of rake and clearance are easily changed to give the best results by changing the position of the tool.

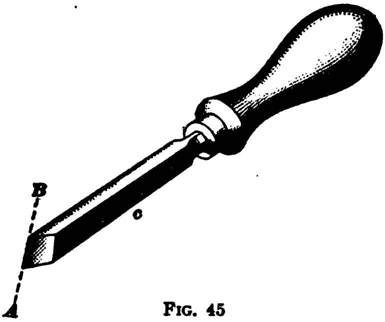


FIG. 45

57. Round-Nosed Hand Tool.—The round-nosed tool shown in Fig. 47 is used for finishing concave curves. The under side lies flat on the rest when it is used. Hand tools are commonly made from worn-out files of either square or rectangular section. Their points can be ground to any particular shape best suiting the work. They are also made from flat files ground to any required curve, either right-hand or left-hand, and are used for finishing turned cast-iron surfaces in the lathe preparatory to polishing. They are of the same general form as the tool shown in Fig. 47.

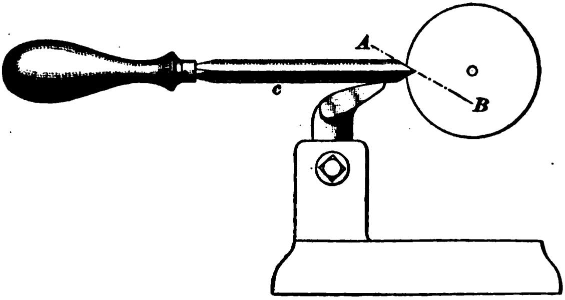


FIG. 46

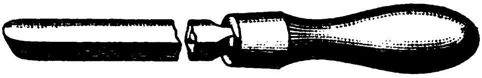


FIG. 47

58. **Three-Cornered Hand Tool.**—The three-cornered tool shown in Fig. 48 is made from a three-cornered file from which all of the teeth have been ground on a wet wheel. The end is ground to a sharp point, which gives three sharp cutting edges, as *a b*. This tool is very largely used to scrape center holes and to remove burrs from the ends of plain holes.

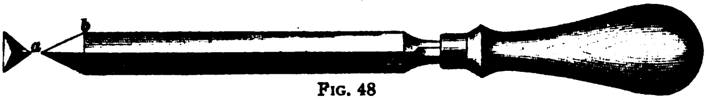


FIG. 48

TOOL GRINDING

59. **Shapes of Tools.**—It is a common practice in some shops for each man to grind his tools to suit himself, the grinding being done on grindstones or special emery wheels for tool

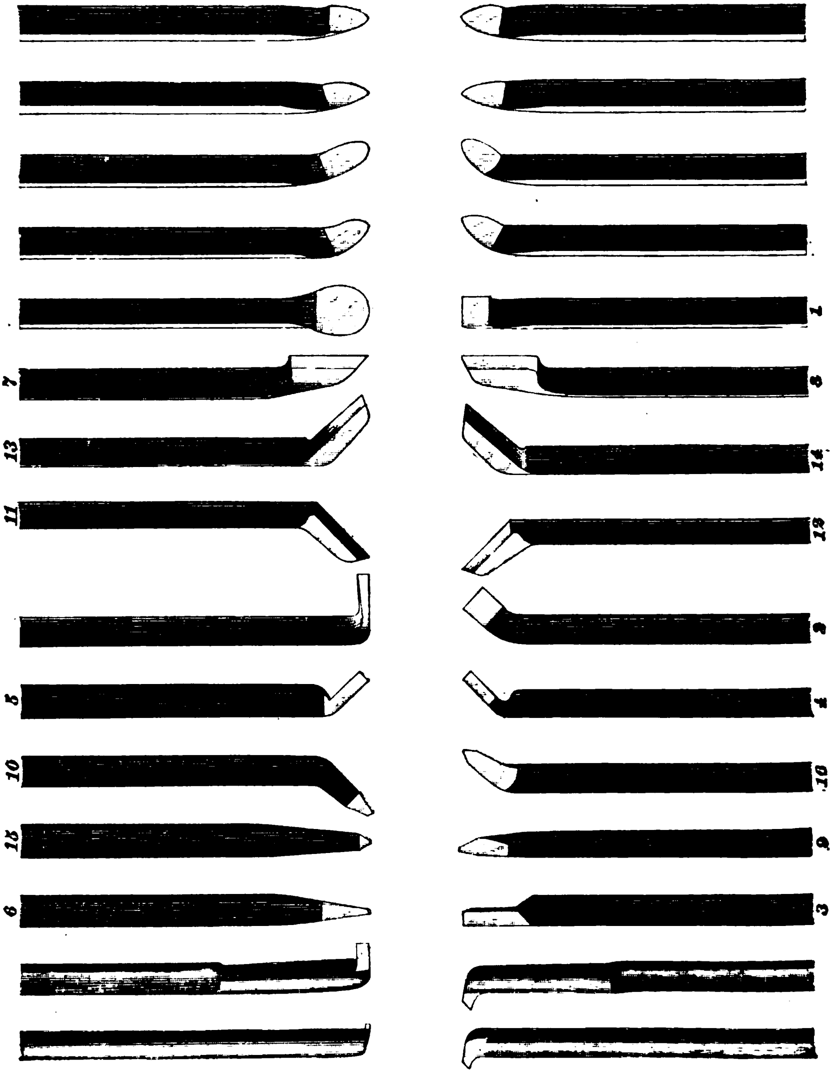
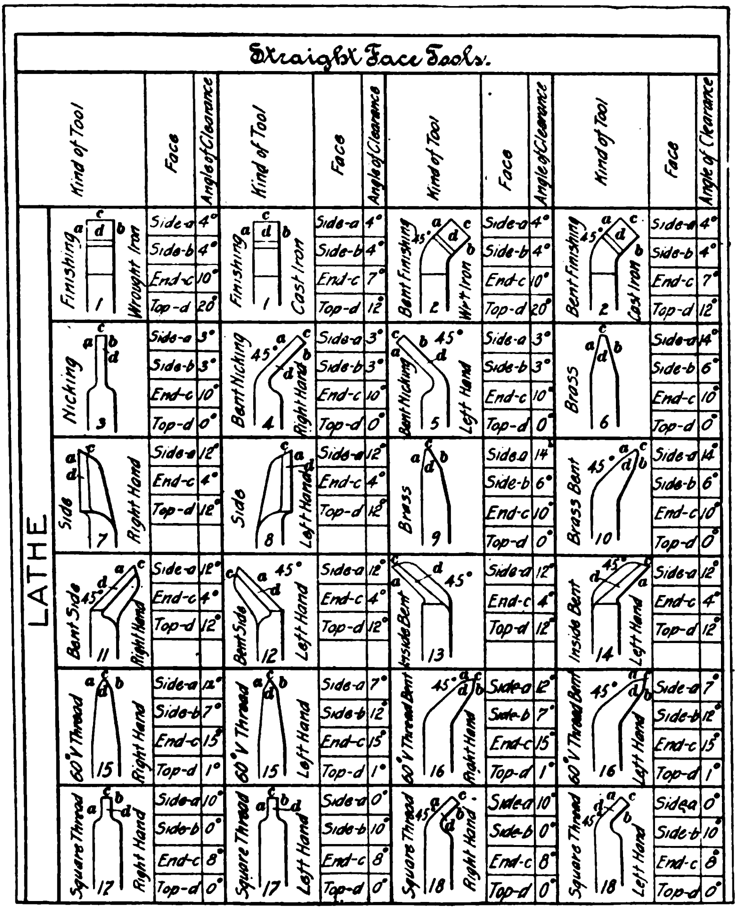


FIG. 49

grinding. The result is a very great stock of steel, which is necessary to make up the sets of tools for the different machines, and an almost infinite number of shapes. The best-managed shops have now adopted a system whereby the tools are systematically and scientifically ground in a central tool room by one set of men. There are a number of automatic tool grinders in use designed for this purpose. All tools are kept in a tool room and are checked to the workmen as used. A few typical lathe



Straight Face Tools.

LATHE

Kind of Tool	Face	Angle of Clearance	Kind of Tool	Face	Angle of Clearance	Kind of Tool	Face	Angle of Clearance	Kind of Tool	Face	Angle of Clearance
Finishing 1 Wrought Iron	Side-a Side-b End-c Top-d	4° 4° 10° 20°	Finishing 1 Cast Iron	Side-a Side-b End-c Top-d	4° 4° 7° 12°	Bent Finishing 2 Wt Iron	Side-a Side-b End-c Top-d	4° 4° 10° 20°	Bent Finishing 2 Cast Iron	Side-a Side-b End-c Top-d	4° 4° 7° 12°
Nicking 3	Side-a Side-b End-c Top-d	3° 3° 10° 0°	Bent Nicking 4 Right Hand	Side-a Side-b End-c Top-d	3° 3° 10° 0°	Bent Nicking 5 Left Hand	Side-a Side-b End-c Top-d	3° 3° 10° 0°	Brass 6	Side-a Side-b End-c Top-d	14° 6° 10° 0°
Side 7 Right Hand	Side-a End-c Top-d	12° 4° 12°	Side 8 Left Hand	Side-a End-c Top-d	12° 4° 12°	Brass 9	Side-a Side-b End-c Top-d	14° 6° 10° 0°	Brass Bent 10	Side-a Side-b End-c Top-d	14° 6° 10° 0°
Bent Side 11 Right Hand	Side-a End-c Top-d	12° 4° 12°	Bent Side 12 Left Hand	Side-a End-c Top-d	12° 4° 12°	Inside Bent 13	Side-a End-c Top-d	12° 4° 12°	Inside Bent 14 Left Hand	Side-a End-c Top-d	12° 4° 12°
60° V Thread 15 Right Hand	Side-a Side-b End-c Top-d	12° 7° 15° 1°	60° V Thread 15 Left Hand	Side-a Side-b End-c Top-d	7° 12° 15° 1°	60° V Thread Bent 16 Right Hand	Side-a Side-b End-c Top-d	12° 7° 15° 1°	60° V Thread Bent 16 Left Hand	Side-a Side-b End-c Top-d	7° 12° 15° 1°
Square Thread 17 Right Hand	Side-a Side-b End-c Top-d	10° 0° 8° 0°	Square Thread 17 Left Hand	Side-a Side-b End-c Top-d	0° 10° 8° 0°	Square Thread 18 Right Hand	Side-a Side-b End-c Top-d	10° 0° 8° 0°	Square Thread 18 Left Hand	Side-a Side-b End-c Top-d	0° 10° 8° 0°

FIG. 50

tools ground on one of the standard tool grinders are shown in Fig. 49, and Fig. 50 is a chart showing the angles to which the tools are ground. The numbers placed opposite the tools in Fig. 49 correspond to similar numbers in Fig. 50.

60. Effect of Improper Grinding.—A diamond point that is correctly ground and set is shown in Fig. 51. All grinding for the purpose of sharpening this tool should be done on the top face, so as to keep the correct shape. When correctly set, as shown, the tool cuts along the edge *a b* and reduces the 1⅜-inch stock to a diameter of ⅝ inch. When the tool is ground incorrectly, so that the cutting edge is *a c*, it will then cut the work as indicated by the dotted lines, and will reduce it to a diameter of only 1 inch, so that a second cut will be necessary to bring the work to the desired size. Moreover, the power required with the incorrectly ground tool will be practically the same as with the correctly ground tool.

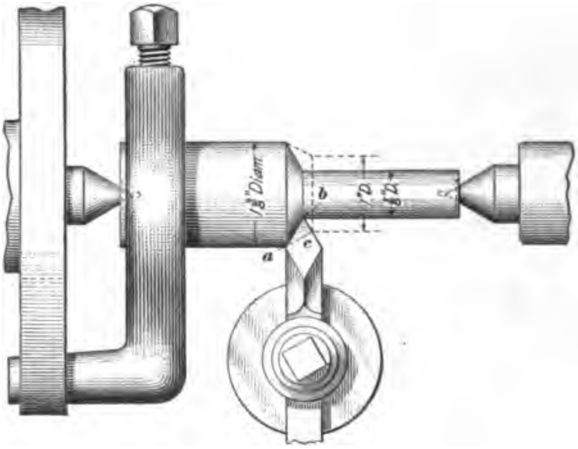


Fig. 51

CHUCKING TOOLS

61. Method of Holding Chucking Tools.—When the holes are 3 inches or less in diameter, they can be more rapidly and accurately bored by using special boring tools called chucking tools. These tools may be held in a special holder on the carriage, or in the tailstock in place of the dead center. The latter method is the more common. When a chucking tool is to be held in the tailstock spindle, care should be taken to see that it is perfectly in line with the live spindle; otherwise, the hole will be spoiled.

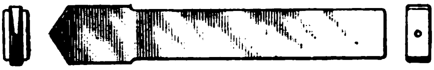


FIG. 52

62. Flat Drills and Holders.—For rough boring in cored holes, the flat drill shown in Fig. 52 is sometimes used. It may be made from flat bar steel with the point ground like the point of an ordinary flat drill. The other end has a large center hole for receiving the dead center. In using the drill, a specially made holder is employed, as shown in Fig. 53. The holder consists of a flat piece of iron or steel with one end bent at an angle. The slot *a* cut through the end is sufficiently large to allow the drill to pass through.

63. Operating a Flat Drill.—When the flat drill is used, the holder, Fig. 53, is clamped in the tool post so that the center of the slot *a* comes in line with the dead center. The drill is passed through the slot and fed into the work by pressure on the dead center, and the holder keeps the drill from revolving. In starting the cut, there will be a tendency for the drill to wabble, owing to the irregularity of the cored hole. To start the drill true, a monkeywrench is clamped on the drill, near the holder, as shown in Fig. 54. By pulling on the wrench in the direction that the work turns, the drill is rotated sufficiently to make it pinch against the opposite sides of the slot

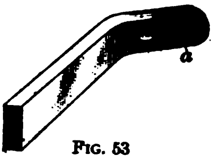


FIG. 53

in the holder. This prevents it from moving sidewise and makes it a very stiff two-edged boring tool. While in this position, the drill is fed into the work until the entire cutting edge is in metal, after which the wrench is pulled lightly to keep the drill from chattering. Holding with the wrench causes the drill to start true, if the wrench is pulled so hard that the drill cannot move sidewise. When once started, this drill cuts well, but the hole will not be truly cylindrical. Care should be taken to see that the dead-center end does not slip off the center, or both the hole and the operator may be injured.

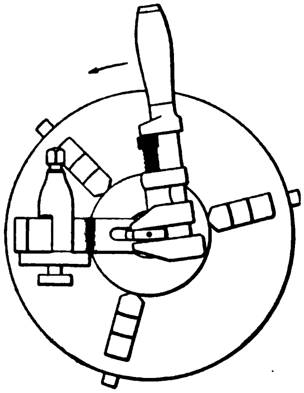


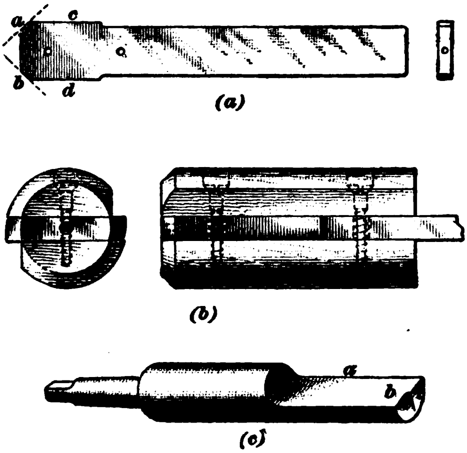
FIG. 54

64. Flat Reamers.—To finish the hole more perfectly, a flat reamer, shown in Fig. 55 (*a*), may be used in the same manner as the flat drill. This reamer is made of flat bar steel, and turned parallel on the sides *c* and *d* to a diameter equal to the diameter of the desired hole. The cutting edges are the beveled edges *a* and *b*. This reamer is sometimes covered with wooden guides, so that it will follow the hole being reamed. The wooden faces are used to keep the reamer from chattering and to guide it so that the holes will be more nearly accurate. Such wood-covered reamers are called *wood reamers*.

The wooden faces are made of two blocks of any hard wood, oiled, and clamped on by wood screws, as shown in (*b*). After the blocks are clamped in place they are turned or ground to the size of the reamer, and the wood is cut away above the cutting edges to give room for chips to work out.

65. Cannon Drills.—A cannon drill is shown in Fig. 55 (*c*). Half of the stock of the drill is cut away, as shown at *a*, and the cutting edge *b* is at the end. A guide hole is necessary for starting this drill, but when once started true it drills straight.

66. Rose Reamers.—A reamer for following the flat drill, or for use in a machined hole for taking out considerable stock, is known as a rose reamer, one form of which is shown in Fig. 56. The body *a* is ground round and of a uniform diameter equal to that of the desired hole. The rose reamer will remove more stock than the fluted chucking reamer, has fewer flutes, and cuts on the end.



(a)

(b)

(c)

FIG. 55

67. Fluted Chucking Reamers.—For deep holes, the three-fluted chucking reamer shown in Fig. 57 (*a*) is an excellent tool. Because of the spiral flutes, there is less danger of the shavings clogging than there is in the straight flutes shown in Fig. 56. The cutting is done by the beveled edges *a*, and the chips pass away through the larger flutes; the small flutes *b* are formed for clearance and to allow the oil or other lubricant to flow to the point of the reamer.

68. Fig. 57 (*b*) represents a fluted chucking reamer for finishing holes smooth and true to standard size. The cutting edges extend the whole length of the flutes *a b*. When used to follow the rose reamer, the latter should leave about .005 inch of diameter for this reamer to remove in finishing. As it is intended for finishing holes to exact diameter, it should

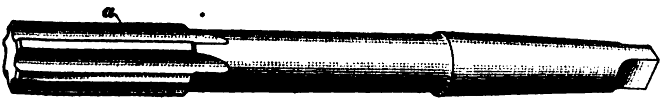


FIG. 56

be used with considerable care; hence, the cutting speed is reduced, and the feed is increased.

69. **Shell Chucking Reamers.**—In Fig. 58 (*a*) is shown a shell chucking reamer of the rose-reamer type, and in (*b*)

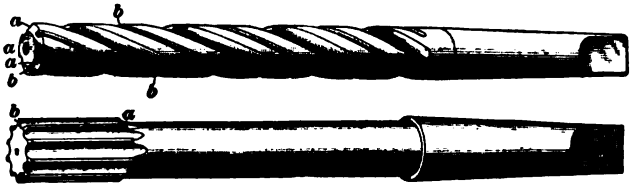
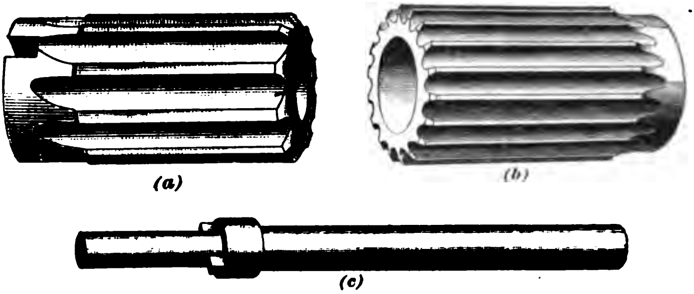


FIG. 57

is shown a shell reamer of the fluted or finishing-reamer type. These reamers are cheaper, and in many cases more convenient, than the solid reamers just described. The shell reamer is simply the cutting part of a reamer made hollow, and used on a shank of any required length. It is cut the same as the regular reamer, and is cheaper, as less tool steel


(*a*) (*b*)

(*c*)

FIG. 58

is required to make it. It is used on an arbor as shown in (*c*). One arbor can be used for a large range of sizes of reamers.

70. **Boring Bars for Chucking.**—A chucking tool that can easily be made for regular work or for odd sizes is shown in Fig. 59. The blade or cutter *c* is held in the bar by a setscrew *s*. Different sizes of cutters may be made at little expense to take the place in many instances of the more expen-

sive standard chucking tools. When the holes to be bored are long, a bar can sometimes be used, as shown in Fig. 60.

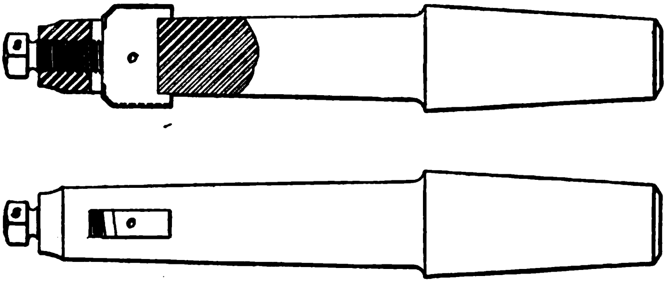


FIG. 59

The cutter *c* is held in the slot cut in the bar by a setscrew *s*. One end of the bar is held in the tailstock spindle, and the other end fits a tapered bushing *b* in the live spindle. Support

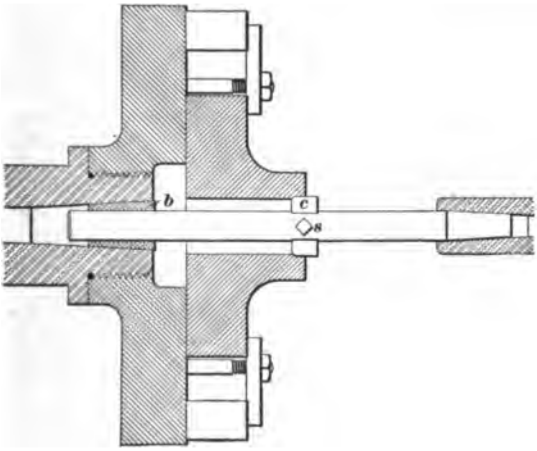


FIG. 60

is thus provided for each end of the bar, which is very desirable when the hole must run true. These cutters are often made in sets of two or three, to be used in regular order to rough and finish the hole.

71. Starting Chucking Tools True.—If the cored hole does not run true, the chucking tool will not start true, the tendency being to follow the cored hole. When it is desired to start the tool true, it may be done by using a common boring tool, and boring out the mouth of the hole to nearly the correct size, so that the tool will enter $\frac{1}{8}$ inch or so. A bearing all around is so given, and the tool held true.

72. Drilling from the Solid.—The tools thus far described, with the exception of the flat drill, are used to enlarge holes that have previously been drilled or cored. The flat drill will either pierce a hole in the solid metal, or it will follow cored holes; but it will not cut so freely as the twist drill. Twist drills are often used in the lathe in a special holder or socket fitted in the tailstock, the drill being fed into the work the same as the chucking tools.

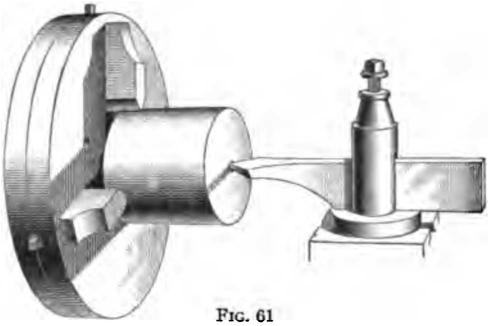


FIG. 61

73. Starting a Twist Drill.—It is essential that the twist drill be started to run true and that its point be centered before the outer corner of the drill has begun to cut. After the outside corner of the drill has entered the work, its position cannot be changed. It is best to make the starting point true by using a tool in the tool post, as shown in Fig. 61. This tool is forged with a thin, flat point and is ground like the point of a flat drill. The hole is started true with the tool, after which the twist drill in the tailstock will follow in the hole previously started. A tool like that shown in the illustration, but made to cut on the front side only, is often used to turn the starting hole true. When this starting tool is not at hand, the twist drill may be started true by placing the butt of an ordinary lathe tool in the tool post, and so adjusting it that it just touches the twist drill. This will steady the point of the drill sufficiently, so that in most cases it will start true. A center fitting the dead spindle may be flattened to form a starting drill.

TYPES OF BORING BARS

74. When the work is heavy or the holes comparatively long, boring can be done by clamping the work to the carriage, and revolving the tool in a bar held between the lathe centers. This bar is called a boring bar. The cutters that do the boring are held in slots in the bar, or in facing heads clamped to the bar.

75. Boring Bars With Fixed Cutters.—A common type of boring bar has a fixed cutter in the center that may project sufficiently to cut only on one end, or it may project equally on each side of the bar and cut at each end. A bar of this type is shown in Fig. 62. The cutter is fitted in a rectangular slot and is held in place by a key *k* driven in at the back. The cutter blade should be turned to the desired diameter before it is hardened. The cutting is done by the points or edges *a* and *b*. When this style of bar is used, it must be twice as long as the hole to be bored, as there must be room for the work at one side of the cutter before it is started, and room for it to pass beyond the cutter after the cut is finished.

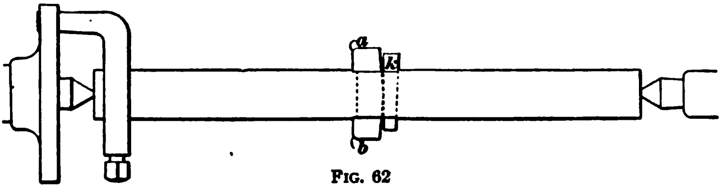


FIG. 62

76. When the hole in the work is large, so that the cutter would project a considerable distance beyond the bar, it is best to fix a cutter head to the bar. Such a head is shown in Fig. 63. It consists of a cast-iron collar carefully fitted to the bar and kept from turning by a key and a setscrew. Four cutters *a* are generally inserted in the head and held in place by the setscrews *s*. The setscrews *b* are used to adjust the cutters. It will be seen that by tightening the screws which stand against the ends of the cutters, the latter will be pushed out of their sockets. As the cutter becomes short, pieces must be put between it and the screw to make the latter effective.

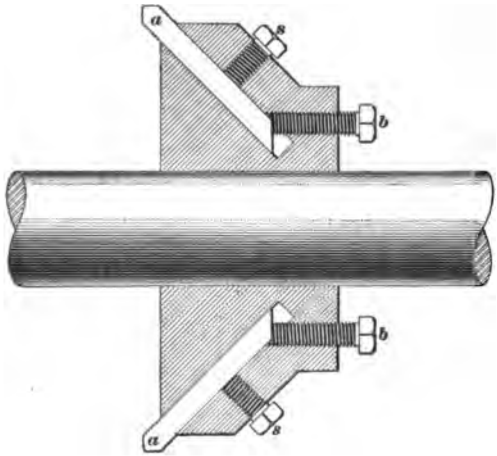


FIG. 63

77. Boring Bar With Traveling Head.—When much boring is done in heavy work, the traveling-head or traverse-head, type of boring bar, shown in Fig. 64, is more desirable, as by this method the work need not be moved along the latter. The bar *a* is fitted with a head *h* that slides on the bar. The head is kept from rotating on the bar by a key that slides in a keyway cut the entire length of the bar. Four cutting tools *b* are used, and are held in place by setscrews *r*. Clamps or wedges are often used to hold the tools in the head. A feed-screw *s*, supported in bearings at either end of the bar, passes through a nut in the sliding head. By revolving the feed-screw, the head is moved along the bar. The feed-screw is generally set in a slot cut in the side of the bar. The screw is thus protected from injury and dirt. A star wheel *w* on the end of the feed-screw is tripped by a stud secured to some part of the

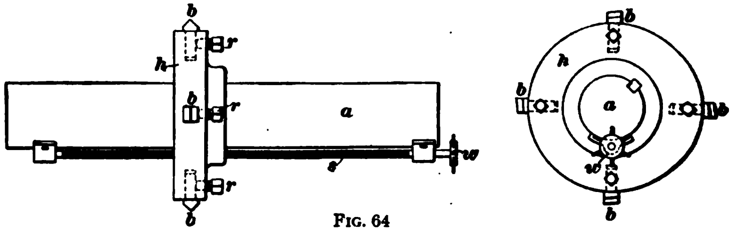


FIG. 64

machine and rotates the feed-screw a part of a turn each time the bar revolves. This movement gives the feed of the head.

CHATTERING

78. Chattering of a tool, which produces a rough corrugated surface on the work, may be traced to many sources. When chattering takes place the action is as follows: The tool is caught by the work and drawn in so as to cut deeply; when it has sprung in a certain depth, the tool and the work are placed under a strain that causes them to spring apart. These performances take place in quick succession, and in more or less of a rhythmical order, producing at times a musical sound, and at other times a most discordant noise. This springing action may be traced to different causes: to the frailty of the work, as in long, slender shafts or large pieces being turned on slender arbors; to the method of driving or rotating the work; to looseness of the spindle in the headstock bearings; to looseness in the cross-slide of the tool rest; to looseness between the lathe centers; or to the peculiar shape or manner of setting the tool. Broad-edged tools have a greater tendency to chatter than narrow ones.

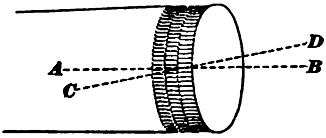


Fig. 65

79. Chatter marks may be prevented by grinding or setting the tool so that its top face has a slight angle of top side rake, just sufficient to keep the broad edge of the tool from falling into the old chatter marks. If, in Fig. 65, the cutting edge of the tool lies in the horizontal line AB, the chatter marks will be parallel to it. These chatter marks can generally be prevented by giving the tool top side rake along the line CD. When remedies in the way of adjustment of the tool and the work and methods of driving have been tried without avail, the spring tool often proves successful in preventing the chatter marks.

LATHE WORK

(PART 3)

LATHE OPERATIONS

CUTTING SPEEDS AND FEEDS

CUTTING SPEED

1. The cutting speeds and feeds of tools should be carefully studied, for the output of work from a machine and the cost of production depend very largely on the cutting speed used. The **cutting speed** of a tool is the speed at which it cuts the work, measured in feet per minute. Before discussing cutting speed, a very clear understanding should be had of its exact meaning. Suppose that the speed of a lathe is such that the tool can cut in 1 minute a shaving that, if it could be straightened, would measure 20 feet in length. The cutting speed is then 20 feet per minute. If the speed of the lathe were such that the tool would cut a shaving 10 feet long in 1 minute, the cutting speed would be 10 feet per minute.

2. The cutting speed and the number of revolutions per minute of the work must not be confused. Suppose that two lathes are running at the same speed of 50 revolutions per minute and that one is turning a piece 1 inch in diameter while the other is turning a piece 2 inches in diameter, the circumference of the 1-inch piece is 3.14 inches and that of the 2-inch piece is 6.28 inches. In the case of the 1-inch piece

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the tool passes over 3.14 inches for each revolution, and in 50 revolutions it will pass over 50×3.14=157 inches=13 feet 1 inch, which is the cutting speed. The 2-inch piece has twice the circumference of the 1-inch piece, and in this case the tool will pass over twice the distance, or 26 feet 2 inches, which is the cutting speed in the second case. It will thus be seen that the cutting speed varies directly with the diameter of the work when the speed of the lathe remains constant.

CONDITIONS GOVERNING CUTTING SPEED

3. Factors Limiting Cutting Speed.—The cutting speed should always be as great as the nature of the work or the durability of the tool will allow. The limit of the cutting speed depends on the durability of the tool. A carbon-steel tool that will cut well when the work is running at a low cutting speed may neither cut well nor endure long when the cutting speed is much increased. The limit may be ascertained by a number of speed trials. At a moderately low speed the tool retains its edge; but if the speed is increased the tool will heat at the point, the temper will be started, and the point will be softened and quickly worn away. As soon as the cutting point or edge is dulled, the friction increases, and greater heat is generated, so that the entire point of the tool will very soon be worn away.

4. Limit of Cutting Speed.—The greatest speed at which the tool will retain its cutting edge a sufficiently long time to turn a fair amount of work is the limit of cutting speed. In cutting iron or steel running at high speed the temper is soon drawn from the tool so that it will not cut. Soft pieces of steel that could easily be turned at a low speed would, when running rapidly, wear away the point of the hardest carbon-steel tool nearly as fast as if the tool were brought against a rapidly revolving emery wheel. The limit of cutting speed varies greatly. In attempting to determine the limit, it will be found to depend largely on the kind of metal being turned, the hardness of the particular piece, whether the cut is a heavy roughing cut or a finishing cut, the diameter and length of the work, and whether the tool is made of carbon steel or of alloy steel.

5. **Effect of Kind of Metal on Cutting Speed.**—The cutting speed is greater for soft metals than for hard. This is illustrated by the high speed used for wood-cutting tools. Copper, brass, babbitt, and similar metals will admit of a much higher cutting speed than cast iron or steel. One reason why copper will admit of a higher cutting speed than iron is because it is softer and less force is required to turn the shaving; consequently, less heat is generated at the cutting point of the tool. Moreover, copper is such an excellent conductor of heat that, as soon as the heat is generated, it is at once conducted from the point of the tool, so that the heat cannot accumulate as fast as in iron or steel. It will be found in turning iron or steel that the work and the shank of the tool keep quite cool, most of the heat being concentrated at the point of the tool and in the shaving. Whatever the metal being turned, the speed must be slow enough to give the heat time to pass into the work before it becomes sufficient to draw the temper of the tool.

6. The tool becomes hotter than the work because it cuts continuously and the friction of the chip on its face is great; whereas, the work is continually changing its position and bringing new points in contact with the tool. The heated part of the work is thus allowed to cool while it is completing the revolution. The shaving, which is light compared with the mass of the work, has no way of distributing its heat except by radiation, and consequently it comes away from the work at a temperature nearly equal to that at the point of the cutting tool. To a certain degree, the rotating of a large piece tends to keep the point of the tool cool; for the tool no sooner severs a part of a shaving at one point on the surface of the work than a second point is presented to it, and so on around the work, the tool constantly being forced into cool metal, which, for an instant, would tend to cool the point.

7. When the lathe tool is exceedingly sharp, a greater amount of heat is generated by the force required to turn the shaving than by the act of severing it. The force required to make a sharp tool cut the work depends on the angle of the top and side faces, and if a blade could be made infinitely thin, with its edge infinitely sharp, it would be found that the mere act of severing a shaving would require very little power. As an illustration, the thin blade of a cheese knife will pass easily through a cheese; whereas, greater pressure is required if a thick, wedge-shaped knife is used. This greater pressure is necessary to bend aside the parts before the blade can enter farther.

8. It may be assumed, therefore, that the heat generated in taking a cut is due to the bending and turning aside of the shaving, and to the friction of the shaving on the top face of the tool and of the work on the front face. This applies to a tool with a sharp edge. The peculiar wear sometimes noticed on tools that are considered excellent is thus partly explained. Fig. 1 shows a tool as it is sometimes worn after a cut is taken on steel. It will be noticed that the cutting edge *a b* has retained its original sharpness and that immediately behind it a small groove *c* has been worn.

9. This peculiar wear may be explained by assuming that the cutting edge possesses an unusually fine temper, being of sufficient hardness to retain its keen cutting qualities and at the same time is tough enough not to break. This keen edge severs the shaving easily, and causes but little heat. As fast as it enters the work it comes in contact with cool points, which tends to keep the edge cool. At the instant the shaving is severed or cut loose from the work, it is at once turned from its course by sliding on the top face of the tool. The heat thus generated slightly softens the top face of the tool, and the shaving tends to wear away this top face as it turns and slides from the tool. This is more apt to occur when light cuts are being taken at high speeds.

10. At high speeds the edge of the tool is more rapidly cooled because of the succession at which the cool points on the work are brought against it. At slower speeds, with heavy cuts, the heat from turning the shaving overbalances the cooling action of the work; consequently, the edge of the tool suffers from becoming hot. It must not be inferred from these statements that a tool will stand better at a high than at a low rate of speed, for such is not the case. If, in the case of the tool shown in Fig. 1, the speed had been slightly reduced, the tool would have done the work just as well and would not have been worn on the top face. The limit of cutting speed had been reached in this case, and increasing it even slightly would have ruined the tool.

11. The power required to make a tool cut depends on the angles made by the cutting faces, and the harder the material being cut, the less sharp should the cutting angle be. A large angle of the cutting faces is necessary to support the cutting edge, as, for hard materials the tool must be exceedingly hard, or the sharp edge will be pressed down and rounded. This is what really does occur as a tool dulls. The keen cutting edge is worn off to a rounded surface, as shown much exaggerated at *a*, Fig. 2. As soon as the keen edge becomes rounded, heat is generated at this edge as it is forced to sever the shaving, and the more it becomes rounded the more heat is generated, until at last the tool will cease to cut. If the edge were sufficiently hard to resist the pressure of very hard material, it would be so brittle that, unless the cutting edge were well supported, the tool would break. Keen acute angles would cut more easily and be more desirable if they would not break.

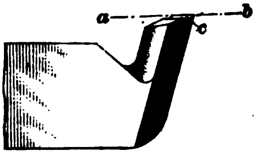

FIG. 1

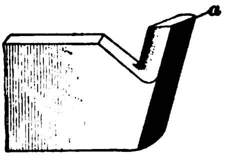

FIG. 2

12. It is thus seen that for hard, tough materials, hard tools with little top rake must be used, but that for softer materials, greater keenness or top rake may be given. Because of the greater power required to force tools having little keenness into the work, a greater amount of heat will be developed. As the limit of cutting speed is governed by the amount of heat generated, the tool having the smaller keenness must be used at a lower speed than the keener one; otherwise, it will pass its heating limit.

This applies in the same way to cuts taken on the same kind of material that varies in degree of hardness. Cast iron, for instance, will be found to vary a great deal in its degree of hardness, some being very soft and some very hard.

13. If two pieces are of the same strength or hardness, the more acute the tool the less the power required to force it into the work. With two tools of the same shape, and taking the same depth of cut in materials of different degrees of hardness, the softer material will require the less power, because of the ease with which the shaving is bent and turned from the tool. The softer material, therefore, develops less heat for the same shape of tool and depth of cut than the harder material; consequently, an increased speed may be used.

14. Roughing Cuts.—Roughing cuts are generally heavy and generate much heat. It therefore becomes necessary to use slower cutting speeds for roughing than for finishing cuts, to prevent burning the tool.

15. Finishing Cuts.—Finishing cuts when short, are best made at a high cutting speed, especially on cast iron, as a smoother surface will result than can be obtained with a slower cut. When a slow cutting speed is used on cast iron, there is a tendency for the shavings to break out of the work slightly in advance of the cutting edge, because of the crystalline structure of the material. This is shown in somewhat exaggerated form in Fig. 3, where a shaving *a* is shown just as it is breaking from the work. When the slow speed is used, the shaving breaks slowly from the work and in so doing breaks into the surface and carries away with it particles of metal that should be left. This leaves a surface that is more or less pitted, and should it be desired to finish it by polishing, these little pits will be found of sufficient depth to make it very difficult to obtain a fine polish. When a higher speed is used, or the tool is ground with a keener cutting edge, this pitting will disappear.

16. Influence of Diameter on Resistance to Cut. Suppose that a diamond-pointed tool is turning a shaft of the diameter represented by the circle *e*, Fig. 4, to the size represented by the dotted lines. The force or pressure on the top face of the tool is measured in a direction at right angles to the face of the tool; therefore, the direction of the force on this tool is along the line *c o* perpendicular to *a o*. This line intersects the circumference of the outer circle at *b*. Now suppose that the tool is taking the same depth of cut on a smaller shaft represented by the circle *g*. The force of the cut will be in the same direction as in the previous case along the line *c o*. The line *c o* intersects the smaller circle at *d*. These lines *d o* and *b o* graphically represent the relative forces required to turn the shaving. In the larger piece, the shaving has a backing and support extending from the point of the tool to the point *b*; but in the smaller piece the shaving is backed only by metal to the point *d*. It will readily be seen that less power will be required to turn the shaving on the smaller piece than on the larger one. Because of this, it is theoretically possible to take a deeper cut on the small piece with the same power required for the original depth of cut on the larger piece.

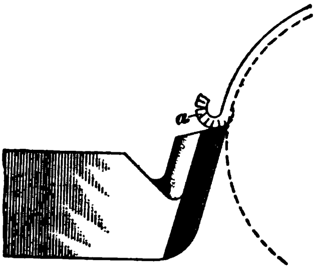

FIG. 3

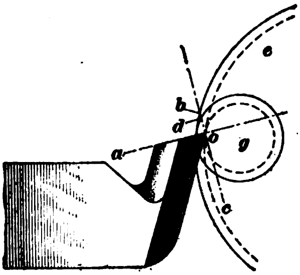

FIG. 4

17. Average Cutting Speeds.—The cutting speed depends on so many conditions that no exact rule can be given that will apply to all cases. Different cutting speeds have been given for the different metals, but these vary greatly. An average, however, has been taken, as given in Table I, which gives fair speeds that may be used under favorable conditions for taking roughing cuts of medium depth with carbon-steel tools. It will be noticed in this table that the cutting speed of brass is considerably greater than that of iron or steel, and that the cutting speed is increased for the small diameters of work, although, theoretically, the diameter of the work should not affect the cutting speed. The cutting speeds given for cast iron are for short cuts taken on very soft castings. Long, continuous cuts on hard castings require a cutting speed somewhat below that given in the table. Experience has shown that a higher cutting speed can be used on machinery steel than on cast iron that is gritty, because of the dulling effect of the grit on the tool.

18. Relation of Tool Steel to Cutting Speed.—When high-speed steel tools are used, the cutting speeds of machine tools may be much increased. This is due largely to the amount of heat these tools will stand before their temper is affected. With some of the best brands of high-speed steel, the rate of cutting speed, compared with that used with carbon-steel tools, is doubled or even trebled. With these tools, shavings may often be cut from tool steel at such a high cutting speed that the heat generated will sometimes be sufficient to draw the temper color on the steel shaving to a dark blue. This is equivalent to a temperature of about 550° F. The best high-speed tools will work well when the point of the tool is at a dark red.

19. Use of Low Cutting Speeds.—Although in most cases it is desirable to work up to the limit in cutting speed, it is not always advisable. With a single-pointed turning tool that may be quickly and easily sharpened, it is a desirable thing to do. In the case of special tools intended to perform certain finishing operations and when the accuracy of the piece depends to some extent on the action of the special tool, then that tool should be favored by using lower cutting speeds. For example, consider a reamer that is to finish holes smooth and true and to an exact diameter within a thousandth of an inch. The size of the hole will depend on the size of the reamer, and when the cutting edge is worn away one-half thousandth of an inch, the reamer will make the holes too small. Such a tool should be handled with care and the

TABLE I

RELATIVE CUTTING SPEEDS OF METALS WITH CARBON-STEEL TOOLS

Material	Diameter of Work Inches	Cutting Speed in Feet Per Minute
Wrought Iron and Machine Steel	½	38
	1	35
	1½	30
	2	28
	2½	25
Cast Iron	1	45
	1½	45
	2	40
	2½	40
Tool Steel	¾	24
	⅞	20
	1	20
	1½	18
Brass	¾	110
	1	100
	1¼	90
	1½	80

cutting speed sacrificed for the sake of maintaining the cutting edge. Taps and dies should not be run at such high cutting speeds as can be used for lathe tools. Chucking tools should also be favored, especially if they are intended to remain at a particular size. Due care and judgment must be exercised in each case to get the best results.

FEED

20. There are two ways of expressing the feed of a tool. Usually, feed is taken to mean the amount of sidewise movement of the tool along the bed during one complete revolution of the work; thus, if a tool moves $\frac{1}{8}$ inch lengthwise of the bed while the work makes one turn, the feed is $\frac{1}{8}$ inch. Sometimes the feed is expressed as the number of revolutions made by the work while the tool moves 1 inch along the bed; thus, a feed of 10 indicates that the work makes 10 turns while the tool moves 1 inch, which corresponds to a movement of $\frac{1}{10}$ inch for each revolution.

21. Relation of Feed to Material.—The best feed to use on a piece of work depends on many conditions. When cylindrical accuracy is desired on wrought-iron or steel shafts, it is best to use a fine feed for finishing, since, with a fine feed, it is possible to use a tool with a narrow point. The narrow-pointed tool will cut more freely and consequently with less spring to the tool and the work. Time, however, is of great importance in machine work, and sometimes coarser feeds will finish with sufficient accuracy. The allowable feed depends on the width of the point of the lathe tool, the point of the tool being slightly wider than the amount of feed per revolution.

22. Cast iron will generally admit of heavier feeds than wrought iron or steel. This is due largely to the difference in the action of the shaving on the tool. In cast iron there is a tendency for the shaving to break immediately when it is turned out of its course by the top face of the cutting tool. This constant breaking of the shaving tends to relieve the tool of undue pressure. In wrought iron or steel the shaving does not break up so easily. When, in turning steel, the broad cutting edge of the tool is set parallel to the axis of the work, any slight pressure that may tend to spring the tool into the work causes the whole broad edge to spring in. The tool will take instantly a very much deeper hold, and, because of the tenacity of the steel, the tool will be carried deeper and deeper until it reaches a point where the strain on the tool balances the pressure of the shaving, at which point the tool will continue to cut at this depth. If the work is not sufficiently rigid to hold its shape while the tool is thus sprung and taking a deep cut, the piece will bend slightly. As the hollow side of the bent piece comes around to the tool, the cut will grow less until the heavy side again comes around, whereupon the cut will be heavier than before, and in most cases the work will be ruined. Broad cutting-edged tools should never be put on a piece of wrought iron or steel, unless the operator is quite sure that there is sufficient rigidity to withstand the cut.

CALCULATIONS RELATING TO CUTTING SPEEDS

23. Finding Cutting Speed.—The cutting speed of a turning tool is the distance in feet traveled in 1 minute by a point on the surface of the work, and this is found by multiplying the circumference of the work, in feet, by the number of revolutions per minute. The circumference of a circle, in feet, is found by multiplying the diameter, in inches, by 3.1416 and dividing the product by 12; thus, a piece 3 inches in diameter has a circumference of $3 \times 3.1416 = 9.4248$ inches, or $9.4248 \div 12 = .7854$ foot. As $3.1416 \div 12 = .2618$, the calculation may be shortened by multiplying the diameter, in inches, by .2618 to find the circumference in feet; that is, for a piece 3 inches in diameter, the circumference is $3 \times .2618 = .7854$ foot. The cutting speed in any case may be found by the following rule:

Rule.—*To find the cutting speed, in feet per minute, multiply .2618 times the diameter of the work, in inches, by the number of revolutions per minute of the work.*

Example.—A shaft that is being turned to a diameter of 2½ inches makes 75 revolutions per minute. What is the cutting speed?

Solution.—Applying the rule, the cutting speed is

$$.2618 \times 2\tfrac{1}{2} \times 75 = 49 \text{ ft. per min.} \quad \text{Ans.}$$

24. Finding Revolutions for Desired Cutting Speed. When a certain cutting speed has been decided for a given piece of work, it may be necessary to find the number of revolutions per minute that the work must make, which may be done by the following rule:

Rule.—*To find the number of revolutions per minute corresponding to a desired cutting speed, divide the cutting speed by .2618 times the diameter of the work, in inches.*

Example.—How many revolutions per minute must a 9-inch steel shaft make to give a cutting speed of 20 feet per minute?

Solution.—Applying the rule, the required speed is

$$\frac{20}{.2618 \times 9} = 8\tfrac{1}{2} \text{ R. P. M.} \quad \text{Ans.}$$

25. Finding Time Required to Take Cut.—The time required to take a cut over a piece of work of known diameter, with a given feed and a fixed cutting speed may be calculated by the following rule:

Rule.—*To find the time, in minutes, required to turn a piece of work, multiply .2618 times the diameter of the work, in inches, by the length of the work, in inches, and divide this product by the cutting speed multiplied by the feed, in inches, per revolution of the work.*

Example.—How long will it take to turn up a flywheel 20 feet in diameter and with a 24-inch face if the cutting speed is 15 feet per minute and the feed is ½ inch per revolution of the wheel?

Solution.—A diameter of 20 ft. is equal to 240 in. Applying the rule, the time required is

$$\frac{.2618 \times 240 \times 24}{15 \times \frac{1}{2}} = 201 \text{ min.} = 3 \text{ hr. } 21 \text{ min.} \quad \text{Ans.}$$

26. Advantage of Coarse Feeds.—When the finishing cut is being taken on a large piece, it is desirable to have the tool retain its sharp edge until the operation is completed, so that the last part of the cut will be as smooth and true as the first. On heavy work it is best to use a coarse feed and slow cutting speed. When the tool dulls, it also becomes necessary to resharpen it before the cut is completed. As it takes some time for the work to make a revolution, by the time the tool is adjusted to the same depth as before and the feeds are again working, much time is lost.

27. Suppose that, in the example of Art. **25**, a feed of $\frac{1}{16}$ inch and a cutting speed of 18 feet per minute were used. The time required would then be

$$\frac{.2618 \times 240 \times 24}{18 \times \frac{1}{16}} = 838 \text{ minutes}$$

This is equal to 13 hours 58 minutes. Also, the length of shaving with $\frac{1}{16}$-inch feed would be $3.1416 \times 20 \times 24 \div \frac{1}{16} = 15{,}080$ feet, or nearly 3 miles. No tool would cut nearly 3 miles of shaving without getting dull, and the time would be considerably more than is necessary. On such a piece, the feed would be increased to nearly 1 inch per revolution and the cutting speed reduced to about 15 feet per minute. This would reduce the length of the shaving to 1,508 feet, and would require about 100 minutes, or 1 hour 40 minutes. The time is thus decreased to about one-eighth the original, which makes it possible to use a tool that will last throughout the cut.

PLAIN CYLINDRICAL TURNING

PREPARATORY WORK

LOCATING CENTERS

28. Suppose that the piece of work to be turned is to have, when it is finished, the shape and dimensions shown in Fig. 5. The original bar, or *stock*, as it is called, must then be longer than 12 inches, to allow the ends to be squared to the correct length; and it must exceed 2 inches in diameter, to allow the outer surface to be turned off. Suppose that the stock is 12¼ inches long and 2⅛ inches in diameter. The first step, then, is to center the ends of the work, after which center holes must be drilled and reamed so that the work can be held between the centers of the lathe.

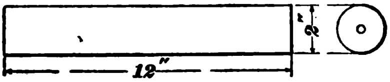

FIG. 5

29. Locating Centers by Dividers.—The operation of locating, drilling, and reaming the center holes is one of importance and requires careful attention. Various methods are used for locating center holes, depending on the shape of the piece and the number of pieces to be centered. If the stock is round and true, the center may be located roughly by placing the work on a flat surface and using a pair of dividers, set to about half the diameter of the work, for scribing lines on the end, as shown in Fig. 6. The dividers are drawn across the chalked end of the work, scribing one line; the work is turned a quarter revolution and another line is scribed, and

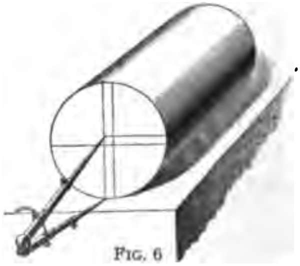

FIG. 6

so on until there are four lines intersecting, as shown. The center of the square at the center is approximately the center of the work, provided the dividers were held at the same angle with the work each time a line was scribed. A prick-punch mark made in the center of the square locates the trial center.

30. Locating Centers by Surface Gauge.—Instead of the dividers, a surface gauge or scriber block may be used for scribing the lines. Fig. 7 shows how a surface gauge *a* may be used for locating centers on a bolt *b*. In this piece, it is desirable to make the center true with the stem or shank of the bolt, as the head cannot always be depended on to be forged true with the shank. The bolt is placed in the **V**'s of two blocks *c*, which should hold the bolt high enough from the bench or table that the head will not touch when the bolt is revolved in the **V**'s. The scriber point of the surface gauge is then set to about the center of the work and the four lines are scribed, one at each quarter-turn, intersecting as shown.

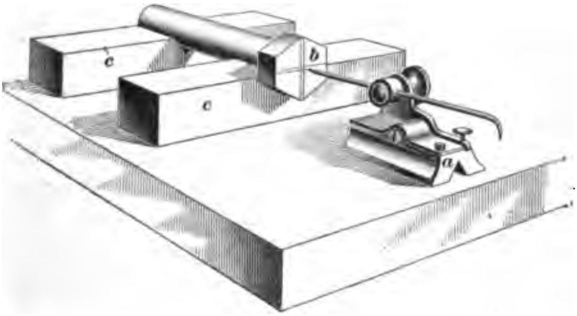

FIG. 7

31. Locating Centers by Hermaphrodites.—Another method of locating the center is by the use of hermaphrodites, as shown in Fig. 8. The hermaphrodites are set so that the pointed leg comes near the center of the work. With the bent leg at the respective points *a*, *b*, *c*, and *d*, four arcs are scribed, intersecting as shown, and forming a small, four-sided central figure. The center *e* of this central figure is the approximate center of the end of the work.

32. Locating Centers by Cup Center.—When there are many pieces to be centered, time can be saved in locating the centers by the use of a cup center, shown in Fig. 9. The conical opening in the end is placed over the end of the work, as shown, and a light blow on the prick punch *p* with a hammer is sufficient to mark the center. If the end of the work to be centered is untrue, as in Fig. 10, or if the device is not held true on the end, as in Fig. 11, it will not locate the center accurately. The line *a b* shows the center line of the work, and *c d* the center line of the punch. Fig. 12 shows a centering device that insures that the punch and the work will be held in line, but does not overcome errors due to untrue ends, as shown in Fig. 10.

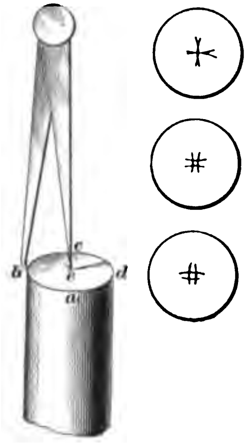

FIG. 8

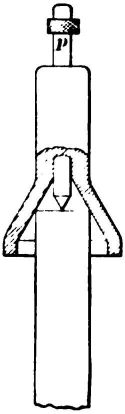

FIG. 9

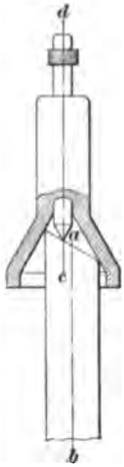

FIG. 10

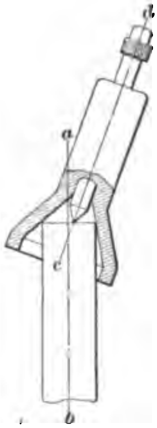

FIG. 11

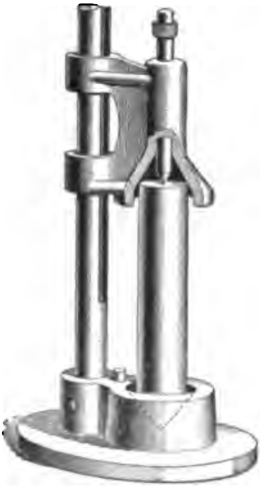

FIG. 12

33. Testing Location of Centers.—When the stock, or the rough piece to be finished, is very close to the finished size, it is best to test the accuracy of the location of the centers before they are actually drilled and reamed. In the case of light work this may be done by supporting it between the centers of the lathe, allowing the points of the lathe centers to enter the prick-punch marks made in the ends of the work. While thus supported, the work should be revolved rapidly by drawing the hand quickly across it. While the work is thus spinning on the center points, chalk is so held that it will just touch any high spot on the work. If there is an untrue end or a high side, the chalk will mark the high place. The center mark is then moved, until the work will run with sufficient accuracy to insure the correct location of the centers.

34. Changing Center Marks.—The center marks in the ends may be changed slightly in location by using a prick punch and slanting it in the direction in which it is desired to move the mark, as shown in Fig. 13 (*a*), or the prick punch may be held at one side of the center, as shown in (*b*). In the latter case, the point of the punch will move toward the old center when struck, but will draw the center to one side, as desired. When the centers are satisfactorily located, they should be made quite large with the punch, for the purpose of making a starting point for the drill. If only a very small mark is made in locating the center, the drill may begin drilling at some other point than the desired place.

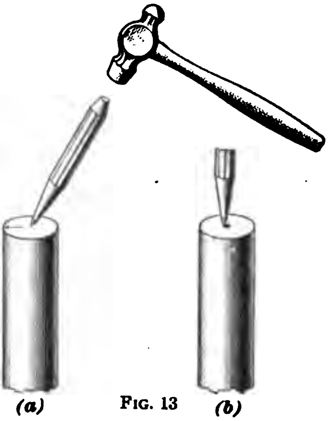

FIG. 13

FORMING CENTERS

35. Centering Machines.—When a great deal of work is to be centered, much time and expense can be saved by the use of special centering machines, a type of which is shown in Fig. 14. The use of such a machine makes it unnecessary to locate the centers as just described. The machine illustrated is fitted with a universal chuck *a* that holds the work to be centered accurately in line with one spindle of the machine. If the work is long, the end is supported in the V-shaped rest *b*, and while in this position it is drilled and reamed. There are two spindles *c* and *d*, the first carrying a drill and the second a reamer, and these can alternately be brought in line with the center of the work. After the machine is once adjusted, it will drill and ream all pieces to the same depth and size.

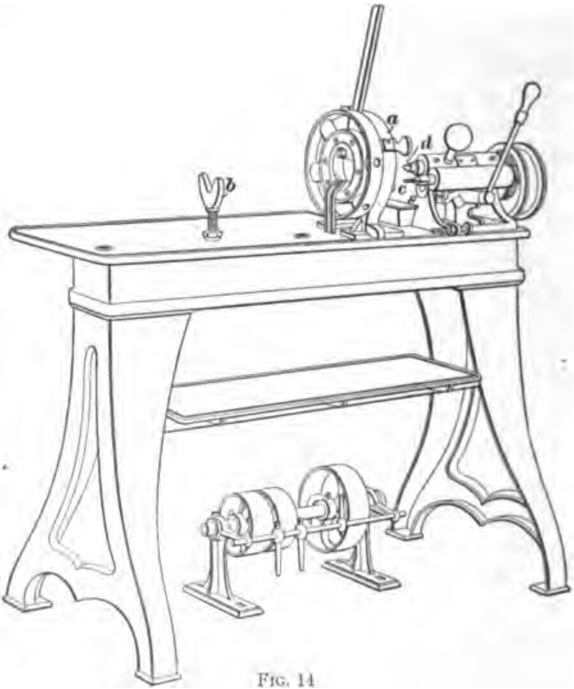

FIG. 14

36. Drilling and Reaming of Center Holes.—If a centering machine is not at hand, the drilling and reaming may be done on a sensitive drill, on a speed lathe, or on the engine lathe on which the work is to be turned. It is usually necessary to drill and ream center holes in very large shafts with a ratchet drill or a hand brace while the shafts lie on the floor or are blocked up on the **V**'s of the lathe. When on the **V**'s, a shaft is in line with the centers and the dead spindle is used to feed the drill or reamer.

37. Centering Tools.—The tools used to make center holes are a twist drill to form the first or clearance hole and a countersink or center reamer of the form shown in Fig. 15 (*a*) and (*b*). Most of the small center drilling, however, is done by using the combined drill and reamer shown in (*c*), and running it to the required depth. This tool drills the clearance hole and reams the tapered part true with it, which is important when accurate work is to be done. The protected-center drill shown in Fig. 16 (*a*) is similar to the combination drill and reamer, but has two cutting edges at right angles to its axis, producing the protected hole shown in (*b*). The protected center is very convenient when facing the ends of work, and is best for rather large work.

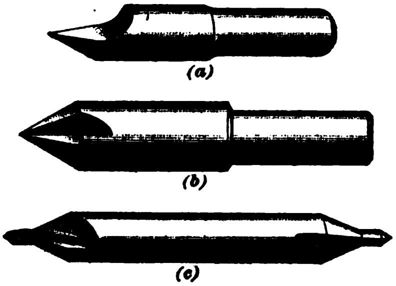

FIG. 15

38. Making Center Holes.—The ordinary hand process of making correctly formed center holes without special tools consists of feeding a center drill $\frac{1}{16}$ to $\frac{1}{8}$ inch in diameter into the stock deep enough to extend from $\frac{1}{8}$ to $\frac{1}{4}$ inch beyond the point of the lathe center and then reaming the hole to

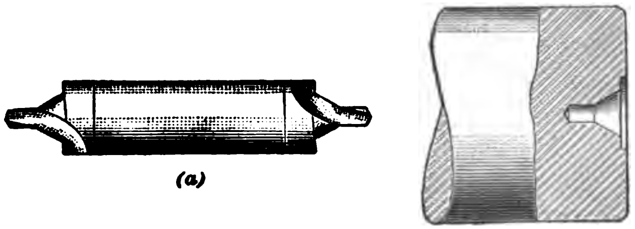

FIG. 16

the angle of the lathe centers. The drills and reamers used should always be proportionate to the size of the work. Small work requires small centers, and large work requires large centers; and they should be larger for high-speed than for carbon-steel tools.

39. Correctly Formed Center Holes.—A section through a properly formed center hole, showing how it should fit the lathe center, is given in Fig. 17 (*a*). It is reamed to an angle of 60° to fit perfectly the angle of the lathe center; also, the drill hole extends into the work sufficiently deep to prevent the extreme point of the lathe center from bearing against the work. The practice employed by some workmen of forming the center holes by simply making very large center-punch marks in the ends of the work should not be allowed, as it is impossible to produce accurate work with such center holes; besides, the work will soon wear or break off the points of the lathe centers. When very large center holes are required to support extra-heavy pieces, particularly in cast iron, it is an excellent plan to cut several oil channels *a*, as shown in (*b*). It is also well to fill the end of the center hole *b* with wool, felt, or waste saturated with oil.

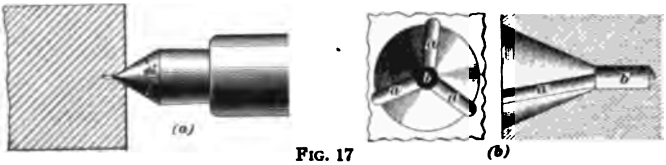

FIG. 17 (b)

40. Placing Work on Centers.—After centering and thoroughly cleaning both center holes, the work is ready for the lathe. A lathe dog is slipped on one end of the work, and some machine oil is put in the center hole of the other end, and the tailstock is adjusted to the proper position to hold the work between the centers. In adjusting the tailstock on the bed, it should be so clamped that it will not be necessary to run the tailstock spindle out very far to reach the work, as greater stiffness is secured by keeping the spindle well in the tailstock. The work is placed on the live center and the dead center is carefully run into the center hole. Care must be taken not to jab the end of the work with the dead center and to adjust the dead center so that the work is free to turn, and at the same time is held so tightly that there is no lost motion. The operator must also see that the tail of the dog fits loosely in the notch of the face plate. Sometimes the dog is too small and the tail of the dog bottoms in the face-plate slot and holds the work away from the live center, as shown in Fig. 18. The work is thus prevented from running true.

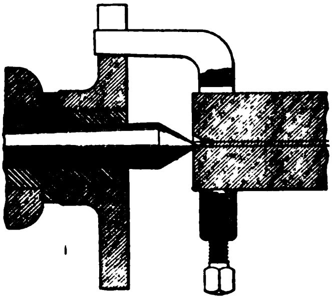

FIG. 18

TURNING OPERATIONS

SQUARING ENDS OF WORK

41. Tool Used for Squaring Ends.—Any work that is to be turned between the centers of a lathe should have its ends squared, or made flat and true at right angles to its center line, before the cylindrical surface is turned. The tool used for this operation is the side tool, sometimes called the *knife tool*. Side tools are made both right-hand and left-hand, so that they can be used for squaring opposite ends of a piece of work. The tool used for this particular operation is a right-hand tool.

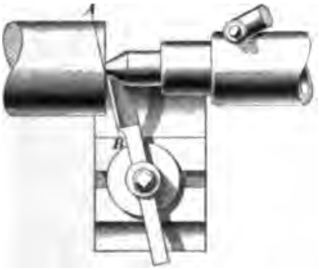

FIG. 19

42. Setting of Side Tool.—The side tool should be so clamped in the tool post that the cutting edge *A B*, Fig. 19, makes an angle of from 10° to 15° with the end of the work.

The tool should be clamped as close to the cutting edge as possible, in order to insure stiffness, and the height should be adjusted so that the cutting edge will be level with the center of the work.

TAKING THE CUT

43. On all machine work there are two classes of cuts used, namely, the *roughing cut* and the *finishing cut*. The roughing cut, as its name implies, is the first heavy cut taken over the work for the purpose of blocking out or roughing the work very close to size, the object being to remove the metal in the shortest possible time. Roughing cuts are therefore made as heavy and as deep as the machine will stand. The finishing cut is the last cut taken on the piece and is intended for finishing the work to exact size, and at the same time making it smooth and true. In order to obtain these results, the tool must be very sharp and keen.

44. Roughing Cuts.—When using the side tool, the cut is started at the center of the work. The tool is moved sidewise by moving the carriage by hand until the tool cuts deep enough to get well under the skin and scale, if the stock is cast iron. The carriage is held stationary in this position while the tool is drawn from the center by means of the cross-feed. These operations are repeated until the desired amount of metal is cut from the end.

45. If much metal is cut from one end, a burr will be left around the center hole, as shown at *b*, Fig. 20. This burr may easily be removed by using the point of the tool, after having first loosened the dead center to admit the tool, as shown. The tool is fed sidewise by hand, in the direction of the arrow, and at the same time the dead center is fed in, to keep the work from dropping off. The chips and shavings that get in the center hole should be carefully removed before any turning is done along the cylindrical surface of the work.

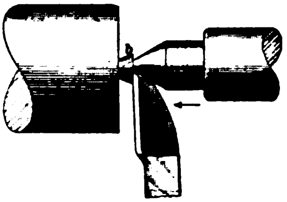

FIG. 20

After each end is roughed off and the piece is very close to the desired length, the center holes should again be drilled and reamed, if necessary, to make them of the proper size to stand the strain when taking the heavy cuts on the outside of the piece.

46. Finishing Cuts.—Before taking a finishing cut, the tool should be reground, if necessary, and then made keen with an oilstone. In order to strengthen the point of the tool and to make the cuts smoother, the cutting edge of the tool is oilstoned with a slight bevel for about $\frac{1}{8}$ inch from the point, as shown at *a*, Fig. 21. The tool is set the same as for roughing cuts, except that the cutting edge stands at such an angle that the end of the work is flat or tangent to the bevel at the point of the tool.

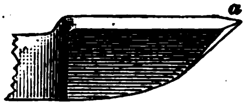

FIG. 21

47. If the point of the tool is not beveled or curved, it will leave deep marks on the work, as shown in a somewhat exaggerated form in Fig. 22, the distance between the marks representing the feed of the tool for each revolution of the work. In some cases, when the work is small in diameter or when true square faces are not required, the edge of the tool is ground straight and set square with the axis of the work, as shown in Fig. 23. When the tool is thus set, it is fed in the direction of the arrow—that is, sidewise to the work—and is not drawn out from the center. The squareness of the end will then depend on the way in which the tool was set.

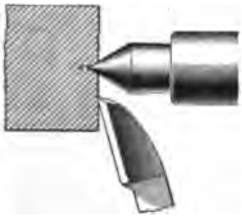

FIG. 22

48. If the tool is set so that only a small part of the edge cuts, and is then drawn out from the center by the cross-feed, a flat surface will be produced. If, however, in making the cut, the carriage is moved toward or away from the work, or

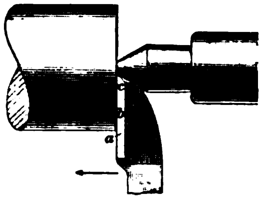

FIG. 23

if the tool dulls or shifts in the tool post, the work will not be true. If the lathe continues to make the work concave or convex, the lathe centers will probably be found out of line. After the centers are lined up, the difficulty will probably disappear. The work may be tested with sufficient accuracy for ordinary purposes by putting a scale or straightedge across the end and holding it to the light, when it will be easy to detect any slight error.

TURNING TO A DIAMETER

49. The tool used for turning a piece of work to the desired diameter is a *diamond point*, or diamond-pointed tool, such as shown in Fig. 24. The quality of the work done depends on the shape of the tool, the way it is set and held in the tool post, and the manner in which it is brought up to the work. This tool is usually formed as in the illustration, which shows a left-hand tool. The cutting is done by the left front edge *a b* and the point *b*. The tool may also be made right-hand.

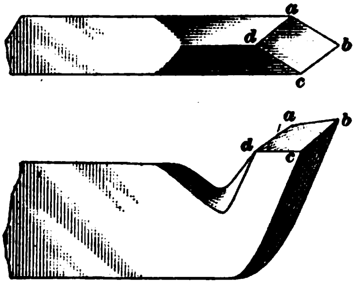

FIG. 24

50. Grinding of Diamond Point.—The diamond point, Fig. 24, is sharpened by grinding the top face *a b c d* so that it slopes back from the point and down toward the right, to give the necessary keenness to the cutting edge *a b*. The two front faces *a b* and *b c* are then ground straight from point to heel by presenting the heel to the wheel first and allowing the grinding to continue upwards until the top face is reached. Starting to grind at the bottom insures taking more off at the bottom than at the top and gives plenty of clearance. After the top and the two front faces are ground, the corner between the two front faces is rounded

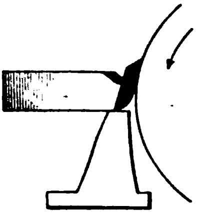

FIG. 25

slightly from the point to the heel to form a durable point that will cut a fairly smooth surface.

51. When grinding lathe tools held in the hand, the point should be finished by holding it up, when applied to the grindstone or emery wheel, as shown in Fig. 25. The water is thus allowed to strike the cutting edge first, keeping it cool. The tool should never be held as shown in Fig. 26 when grinding by hand, as there is danger that it will catch between the wheel and the rest, and cause damage.

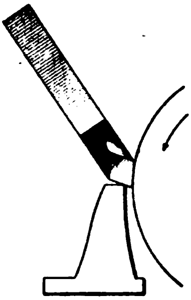

FIG. 26

52. Position of Tool.—The diamond-pointed tool should be clamped in the tool post as close to the cutting edge as possible, to make it rigid. The shank should always be set about square with the work, as shown in Fig. 27. The height of the point above the center of the work is governed by the diameter of the work and the angle of front rake or clearance. In Fig. 28 a tool is shown set at the correct height for turning a piece to the diameter shown by the inner circle; that is, it is set so that a line *A B* drawn from the center through the point *O* of the tool will be at right angles to the front edge *G H* of the tool.

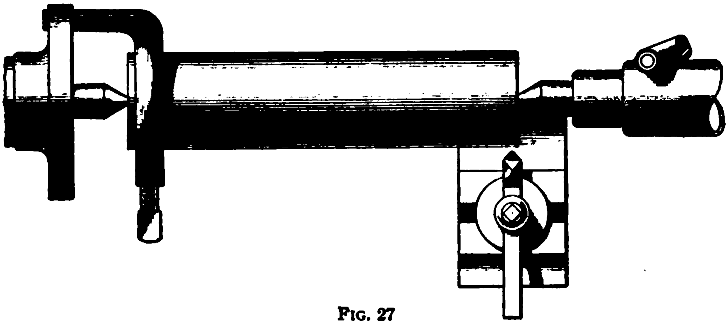

FIG. 27

53. If the tool should be raised, its front being kept at the same angle to the work, it would bring the cutting point above the work, as shown in Fig. 29. It is plain that in this position it would be impossible for the tool to cut. Fig. 28 shows the exact position for a perfect tool, provided it would remain sharp. In practice, the tool dulls and the point rounds off slightly, so that it is customary to set the tool slightly below this position. This theoretical height varies with every diameter of work. Fig. 30 shows a tool correctly set for a piece of large diameter. The dotted lines show the same tool at the same height moved in to cut on a smaller piece shown by the dotted lines. It will be seen that the tool cannot cut work of such small diameter when its point O' is so far above the work. It will also be seen that the point of the tool should be lowered as the diameter decreases, the point O following along the radial line $A B$ until it finally reaches the axis of the work. When clamping the tool in the tool post, care should be taken to see that the point of the tool does not touch the work. When it does touch and the tool clamp is tightened, the edge is liable to be cracked off, as shown in Fig. 31.

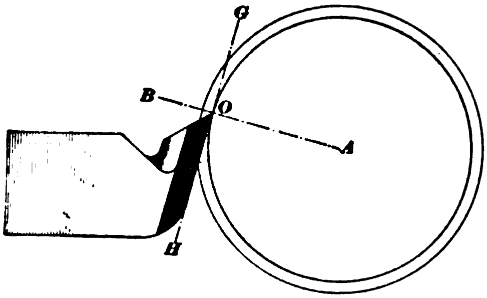

FIG. 28

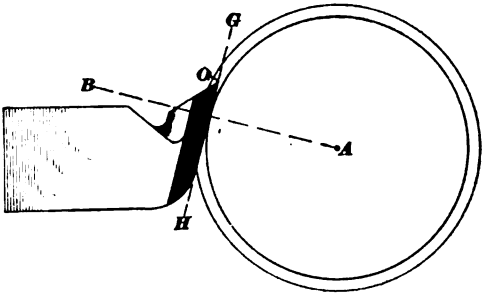

FIG. 29

54. Roughing Cuts.—The excessive material should be removed at one cut, whenever possible. Whether this can be done or not depends on the power of the machine and the strength of the tool, and also on the strength of the piece to withstand a heavy cut without springing or breaking. Some pieces are so frail that a number of light cuts are required to remove an amount of metal that under more favorable conditions could easily be taken off at one cut. Whatever the amount removed may be, there should be left from $\frac{1}{64}$ to $\frac{1}{32}$ inch in diameter over the finished size for the finishing cut. Only in special cases or on rough work is it allowable to rough and finish work with the same cut.

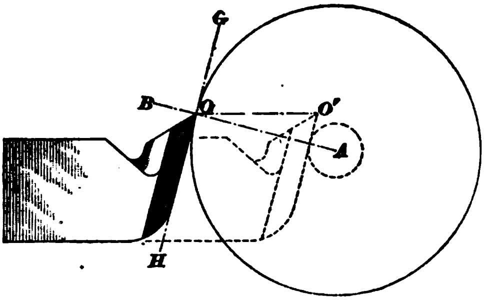

FIG. 30

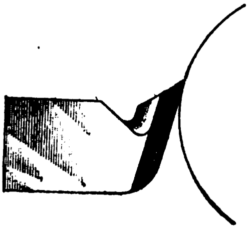

FIG. 31

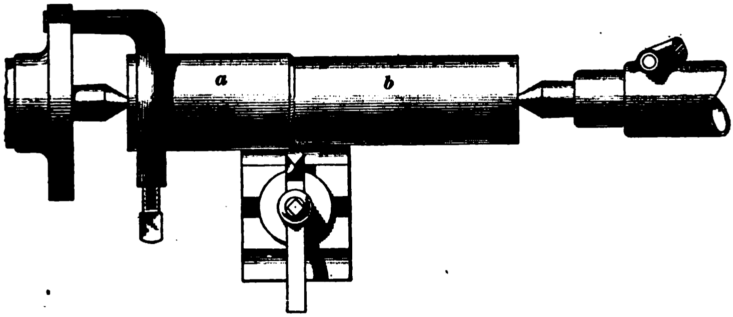

FIG. 32

55. The first roughing cut is started by moving the tool to the end of the work and feeding by hand until it begins to cut. The feed is then thrown in and the tool moves along until a short distance is turned on the end. This part is calipered, and if the cut is not deep enough the tool is set to cut deeper, and another short cut is taken. This process is repeated until the work calipers correctly. The lathe is started, and runs until the tool has fed about half the length of the work, or as far as required. The work will then be as shown in Fig. 32, the part *a* being rough, and the part *b* turned.

56. The tool cannot feed over the entire piece because the lathe dog on the end is in the way. The work should therefore be removed from the lathe and the tool and carriage moved back to the starting point, care being taken not to disturb the cross-slide that moves the tool in or out from the work. The dog is changed to the turned end *b*, Fig. 32, the work reversed, and again put in the lathe. This will bring the work as shown in Fig. 33. The rough end *a* is then turned the same as the turned end *b*, and if the cross-feed has not been moved, the work will be the same diameter at each end, the two cuts meeting in the middle. When it is necessary to take a number of cuts and accurate work is desired, it is better to reverse the work after each cut, as just described, than to take a number of cuts on one end before reversing. The speed of the work, which is 2 inches in diameter, should be about 75 revolutions per minute, provided that the casting is soft, as this will give the desired cutting speed of about 40 feet per minute. The feed should be comparatively coarse, making a thick shaving.

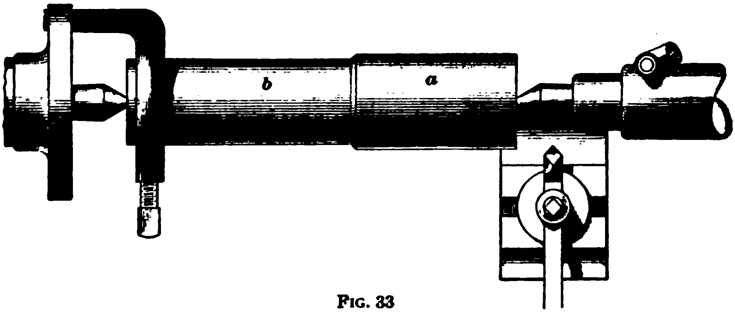

FIG. 33

57. Finishing Cuts.—In taking the finishing cut, considerable skill must be exercised, for if the piece is turned too small, there is no remedy, and if cut rough and untrue, it requires extra labor to complete it. The tool should always be resharpened for the finishing cut. Its shape remains much the same as for roughing, except that the top face may be given a little more slant or top rake. The shapes of tools and also the feed vary considerably, so that what may be considered good practice for this piece would not be the best for heavier work.

58. Use of Calipers.—The diameter of the work is measured either by special gauges or by calipers. When calipers are used, they are adjusted to correct size by trying them over a standard cylindrical gauge of the desired size, or they may be set to size by the use of a scale. In the latter case, they should be so held that the point of one leg of the calipers comes against the end of the scale, and by means of the thumb nut, the calipers are so adjusted that the point of the other leg comes even with the desired line on the scale. Care must be taken to hold the calipers true and to make the adjustment such that by looking squarely by the point of the calipers, it will appear to split the mark on the scale. The thickness of a line on a steel scale is about .002 or .003 inch, and in many instances this amount would be sufficient to spoil a fit.

59. The finishing tool is set to turn the correct diameter by a series of careful trials. A light cut is first taken on the end and run along far enough to give sufficient length of turned part to caliper. The lathe is stopped and this part is carefully calipered. If it is found too large, the lathe is again started, the feed thrown out, and the carriage and tool moved back to the starting point. The tool is moved forwards an amount determined by the judgment of the operator and another cut is taken. The work is again calipered, and if still too large, the operation is repeated until the correct diameter is obtained, when the lathe is started, and the cut taken the required distance. When by calipering it is found necessary to take another cut, the cross-feed screw must be used only to advance the tool. If the tool is displaced, the operator cannot estimate how much to turn the cross-feed screw to move the tool in a little deeper.

60. After the roughing cut, the work should be calipered along its entire length to see whether it is all of the same diameter. If one end is larger than the other, the lathe centers are out of line, or the tool point is so worn away as to cause a taper. If the centers are out of line, the dead center must be adjusted until the two sides of the work are parallel. Care must be taken, however, to locate the cause correctly, in order that the center may not be moved when the tool is at fault.

61. Care in Calipering.—Great skill and delicacy of touch may be acquired by careful calipering, and differences in diameter of .001 inch or less may be detected with ordinary spring calipers. There are two chances for error in calipering, namely, by incorrect setting, and by improper handling of the calipers. When the calipers are correctly adjusted, they are held tightly between the thumb and fingers and passed gently over the work a number of times. It is obvious that the diameter of a cylinder must be measured at right angles to its axis, and if measured at any other angle, as along the line *CD*, Fig. 34, it would be incorrect. The calipers are therefore turned slightly from side to side until the position is found where the calipers pass over most easily. This position, which appears to be the smallest diameter, is the correct one. When the work is of the correct size and the correct position is found, the calipers will just pass over with a very gentle pressure. If the pressure is sufficient to hold the weight of the calipers or if force is required to push them over the work, it is too large.

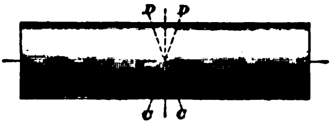

FIG. 34

62. Calipers may very easily be sprung, and it is an easy matter to force a large pair over work $\frac{1}{16}$ or $\frac{1}{8}$ inch too large. When they have been set from a gauge, the work should be turned so that they fit the work with the same pressure and feeling that they fit the gauge. When setting large calipers they should be held, if possible, in the same position that they will be held on the work. If a pair of large calipers is held in a horizontal position, set to a pin gauge lying on the bench, and then held upright by the joint, the legs will spring enough by their own weight to bring the measuring points closer together, and work turned to them will be too small.

FITTING CYLINDRICAL WORK

KINDS OF FITS

63. The term **fit**, as used in lathe work, implies the condition of surfaces and the allowances made in the dimensions of machine parts so that they may be put together to give the desired results. In ordinary machine construction the five kinds of fits commonly used are the *running* or *sliding fit*, the *wringing fit*, the *drive fit*, the *press fit*, and the *shrink fit*. The first is used for parts that work or slide on one another, such as shafts and spindles. The wringing fit is employed for parts that must lie one within the other, without adjustment, and where the size must be maintained, as, for example, in plug gauges and the dead spindles of lathes. The last three forms are used when the parts are to be put together and to remain in fixed relative positions.

SLIDING FITS

64. Requirements.—The most nearly perfect sliding or working cylindrical fits are those whose surfaces most nearly approach perfect cylinders. There must be sufficient difference in diameter to allow the shaft to revolve freely and to admit oil for lubricating. If the shaft and bearing were of exactly the same diameter, the shaft might be turned in the bearing so long as it was kept slightly in motion; but when it stopped, it would be very difficult to start it again. With such perfect fits, the heat generated by the revolving shaft would cause it to expand so that it would be larger than the bearing, and thus change the sliding fit to a solid fit.

65. Allowances.—The closeness of the cylindrical fit depends on the diameter of the shaft, the length of hole, and the condition of the surfaces. Greater differences in diameter are allowed for large shafts than for small ones. In some small machines, spindles about ¼ inch in diameter will require not over .0005 inch difference in diameter, while a shaft 12 inches would require from .005 to .01 inch or more.

66. Making Sliding Fits.—To make a good fit, the surface should be smooth and true. If the hole or bearing is finished by boring, the tool should be made to take a very smooth cut. If there is danger that the work is sprung by chucking, the pressure should be relieved as much as possible before the finishing cut is made. The work should be tested to determine whether it is round and the sides parallel. Whenever possible, it is best to finish holes by reaming, as it tends to make the holes of a standard size and the walls of the holes smooth and parallel. When a running fit is being made, it is best to finish the bearing first, as it is easier to fit the shaft to the hole than to bore the hole to fit the shaft. When gauges are at hand, the cut-and-try method is not used, as the holes are all reamed to pass the limit gauge and the shaft also is turned within limits, so that the pieces will fit each other with sufficient accuracy.

67. Standard or limit gauges are not always used, especially when but a few pieces of a size are to be fitted. In this case, the hole that has been finished must act as the gauge for the shaft. The closeness of the fit depends greatly, as before stated, on the smoothness of the surfaces. The bearing may have been reamed, but the shaft finished with an ordinary finishing cut, and the shaft just slides easily into the bearing. A section through the work showing the conditions of the fit is shown in Fig. 35. Here the bearing touches only on the points of the tool marks,

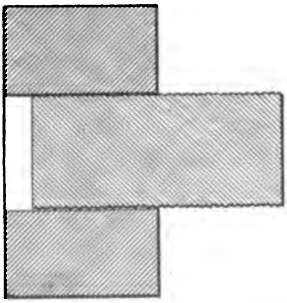

FIG. 35

which are shown in somewhat exaggerated form. It may be seen that if such a fit were allowed to pass, the pressure would come on the points of the tool marks and cause them to wear away rapidly. Furthermore, because of the spiral threads or tool marks around the work, it would be difficult to keep the bearing lubricated, the spiral thread tending to drive the oil out of one end or the other of the bearing, depending on the direction of rotation of the shaft. Because of a lack of oil and the narrow bearing points, such a fit would soon wear loose. This same wearing action would take place if the shaft were smooth and true, but the bore left with clearly defined tool marks.

68. The sliding or running fit is made by first finding the correct size of the hole at both ends. This can be done either by calipering or by trying a solid mandrel in the hole from each end. The calipers are then set to the size of the mandrel at the large end of the hole and a finishing cut is started. When this cut has run from $\frac{1}{8}$ to $\frac{1}{4}$ inch along the shaft, the feed is thrown out and the work is tried in the large end of the hole. If the work will just twist in, the size is right and the cut can be taken as far as required. The surface is then filed carefully with a smooth or dead-smooth file at a speed fast enough to have the work make several turns to each stroke of the file, but not fast enough to burn the file. The tool marks are filed evenly from one end to the other and the piece is oiled and tried in the hole. It is assumed that on this trial the piece wrings clear through the hole and that on removing it there are tight bearing marks in a number of places. The work is replaced in the lathe, the bearing marks touched off by careful filing, and the work polished lightly by repeatedly moving a strip of No. 60 emery cloth from end to end. After being carefully wiped clean of emery, it is oiled and tried in the hole. If it turns easily without shaking, it is a good, close fit.

69. Fitting and Finishing by Grinding.—Much work formerly fitted and finished on the lathe is now finished on the grinder. Lathe work that is to be finished on the grinder is centered in the usual way. The ends and all shoulders are squared to the required lengths, and roughing cuts are made over all cylindrical and tapered surfaces. These roughing cuts may be made at high speed, and with feeds as coarse as the work will stand without excessive springing and chattering. The greatest amount of stock should be removed in the shortest time, and from $\frac{1}{64}$ to $\frac{1}{16}$ inch should be left for the grinder to remove in finishing.

DRIVE FITS

70. In a drive fit the plug or shaft is made slightly larger in diameter than the hole in the surrounding piece, and they are put together by driving. This method is used when the two pieces are intended to keep fixed positions in relation to each other.

71. Allowances.—The allowance for driving, which is the difference in diameter, depends on the diameter of the work, the length of the hole, the condition of the surfaces, and the strength of the enveloping piece. If the hole is long, less difference in diameter is required than when the hole is short. When the hole and the shaft are finished smooth, a very slight difference in diameter makes a great difference in the closeness of fit. If the surfaces are rough, a much greater difference in diameter is allowable. When the surfaces are smooth, a difference of from .0005 to .001 inch will make a very tight fit on work about 1 inch in diameter; but for such a fit as that shown in Fig. 35, where the surfaces are rough, a difference of .002 or .003 inch will be necessary. When these rough pieces are put together, the roughness of the faces is worn down as they are driven over each other, so that, if they should be driven apart, the surfaces would be found to be much smoother than before.

72. Making a Drive Fit.—The size of the hole to be fitted is first determined. If a solid mandrel is available it may be driven into the hole and calipered at the large end. The surface to be fitted is then turned to the size of the mandrel plus the allowance called for by the tightness with which the parts are to fit. If a mandrel cannot be used, an inside caliper or an end measure is employed for setting the outside caliper. The surface is filed to remove the tool marks, and the parts are ready to be assembled.

73. Assembling.—When putting a drive fit together, the surfaces should be oiled. The piece into which the shaft is to be driven should be set on a firm foundation, and the shaft carefully entered and driven to place with a hammer or sledge. Care should be taken not to bruise the work when driving it; consequently, a block of wood, lead, or babbitt is used to strike on. Sometimes the work is so shaped and in such position that a *ram* can be rigged for driving the pieces together. This ram consists of a beam or a round iron bar supported from above by ropes or chains so that it hangs in a horizontal position, level with the work. The ram is drawn back and then pushed forwards so that its end strikes against the work. This is a very effective way of driving. If the work is large and the fit is very close, the driving may be helped by using clamps and bolts, which can be arranged to assist in drawing or forcing the pieces together. With the combined forces of the bolts and the ram, the shaft can be driven to place.

PRESS FITS

74. A **press fit** is one in which the internal part is made so much greater in diameter than the hole it enters that some form of press is required to squeeze the internal part into position. It is also called a *force fit*. The allowance for a press fit is about double that required for a driving fit. The forcing method is used for work too large to be driven together conveniently. This method is also employed for putting engine cranks on shafts, for inserting crankpins in the cranks, and for a great variety of similar work. It is probably used most extensively for putting the wheels on car axles.

75. Classification.—There are two general classes of press fits, namely, the *straight* and the *taper*. When making a press fit the workman should inspect the hole thoroughly to ascertain the smoothness of its surface. He should then caliper it carefully in two or more directions at the entering end, to find whether it is round. He should caliper it also at the other end, to determine its roundness and to detect any taper. If these measurements vary, he should calculate a general average of them and to this average diameter add the allowance required for pressing. The process of turning and fitting the internal part does not differ materially from that used when making a drive fit.

76. Straight Press Fits.—The straight press fit is turned and fitted so that the entering end will just pass into the hole to form a guide for the parts. The necessary allowance is made and the shaft or part is tapered .001 inch to each inch of length of the bearing. This increase provides for the stretch of the hole and for the wear in the hole and on the entering part. If this allowance were not made the fit would not be so tight as intended. If the diameter and length of the bearing surfaces are excessive, less taper will suffice.

77. Taper Press Fits.—A better press fit, known as the taper press fit, is made when required. The hole is bored with a taper of about $\frac{1}{16}$ inch per foot and made as smooth and true as possible. A tapered cast-iron plug is then turned to the same size and taper, to be used as a surface plate for truing the hole. This is done by turning the piece in the hole to mark any high spots or irregularities. These are removed by scraping, and the process is repeated until the hole is true. The taper on the shaft is then turned in the exact position and to the taper specified by the designer, after which it is pushed into the hole to the point specified on the drawing.

78. Allowances.—The allowance for press fits is more than for drive fits. The amount, however, depends on the materials used, the size of the hole, its length, and the condition of the surfaces. It is the practice of some engine builders, who put cranks and crankpins together with press fits, to allow about .0025 inch difference for each inch of diameter. This requires a pressure of from 10 to 13 tons per inch of diameter, depending on the length of the hole, to force the pieces together. This pressure is estimated for diameters that range from 3 to 8 inches.

Car wheels and axles are required to go together within the limits of certain pressures. One railroad company's rule is that, for certain classes of wheels, the pressure required to force the wheel on to the axle shall not be less than 25 tons nor over 35 tons. On an axle 7 inches long and $4\frac{7}{8}$ inches in diameter, an allowance of about .007 inch is made. This requires a pressure of about 30 tons to press the wheel on.

79. Considerable skill is required by the workmen to make press fits; yet, after a little practice, they do it rapidly and can tell within a few tons the exact pressure required to force the wheel into place. In calipering the axles, the exact difference is not always measured by the workman. He may use a snap gauge that has been made sufficiently large to allow for the fit; or, if calipers are used, he may set them to the correct size and test the work so that a certain pressure is required to force the calipers over the work, experience having taught him how great this pressure should be.

SHRINK FITS

80. A **shrink fit** refers more particularly to the method of fitting than to the fit itself. The pieces are fitted in much the same way as for the press fit. When the pieces are put together, the outer piece is heated, which expands the hole sufficiently to let the plug drop in. When the outer piece cools, it contracts enough to grip the pin with great force.

81. When the pieces are large, strong, and of suitable shapes, pressure may be used for putting them together without danger of bending or distorting them. On other classes of work there is no chance to drive or force the pieces together, as, for example, in putting the tires on locomotive wheels. For such large diameters, the difference of diameter in the fit would be so great that very powerful presses would be required to start the tire on the wheel. By heating the tire, it expands sufficiently to let it drop over the wheel center with perfect freedom. Shrink fits are very often employed on small work in shops that have no press to put press fits together.

82. Allowance.—The amount of allowance for shrink fits is generally a little more than for press fits. A fair rule for small work is to allow about .003 inch for the first inch of diameter and to add .001 inch for each extra inch. The amount allowed for locomotive drivers varies, depending on the size of the wheel and the service. Most locomotive builders allow from $\frac{1}{100}$ to $\frac{1}{80}$ inch to 1 foot of diameter.

83. Assembling.—In assembling a shrink fit, the piece that has been bored is heated slightly and evenly. Ordinarily, a heat just sufficient to show a dull red is more than is required. Care should be taken that the piece is never hot enough to scale. The diameters should previously be tested so that there will be no danger that the pieces will not go together when one is heated. If too much allowance has been made, the pieces sometimes catch before the shaft is quite through to the desired place. Unless instantly removed, the shaft will bind so that it will be impossible to move it either way. The shaft begins to expand as soon as it enters the bored piece, and if the difference in diameter is slight at first, it will be very quickly made up by the rapid expansion of the shaft. Therefore, great speed is necessary in putting the pieces together when shrink fits are used, especially on small work. When the pieces are larger, such haste is not important.

84. In shrinking smaller pieces, as soon as the plug is in place, water should be applied to keep it cool. The enveloping piece must not be cooled too suddenly, or it is liable to crack, especially if it is cast iron. If a gear-wheel is being shrunk on a shaft and too much water is applied to the shaft and the hub of the wheel, there is danger that some of the arms will crack. If a cast-iron disk is being shrunk on a shaft and the circumference of the disk is rapidly cooled, there is danger that a radial crack will appear at the edge.

85. Building Up Large Guns.—There is probably no finer example of making shrink fits than that illustrated in the building of the large guns now constructed for the army and navy. These guns are built up, or made of a number of pieces. The first part is a long tube the length of the gun. Over this tube are fitted and shrunk a number of bands or hoops called *jackets*, and over these is fitted another set of hoops. Great skill is required in turning the jackets and the tube so that when the jackets are shrunk on they will exert a certain amount of compressive force, which varies along the length of the tube. A corresponding difference or allowance in the fit must be made to give the various pressures desired. The average allowance is from .0012 to .0015 inch per foot. Great skill is required to bore and turn these pieces to the correct size, as a difference of from .001 to .002 inch may be sufficient to cause rejection. When the jackets or hoops are put on a gun tube, they are first heated by wood

TABLE II

ALLOWANCES FOR DIFFERENT FITS

Diameter of Shaft Inches	+ Allowance on Shaft Inch			− Allowance on Shaft Inch	
	Press Fit	Drive Fit	Shrink Fit	Sliding Fit	Running Fit
1	.001	.00075		.001	.002 to .004
2	.002	.00075		.002	.004 to .006
3	.002	.00125	.00225	.003	.006 to .010
4	.002	.00125	.00300	.004	.007 to .011
5	.003		.00375	.005	.008 to .012
6	.003		.00450	.006	.009 to .015
7	.003		.00525	.007	.011 to .017
8	.004		.00600	.008	.012 to .018

or gas fires. When sufficiently hot, they are dropped over the tube standing on end in a pit. As soon as the jacket is in place, streams of water are turned on the tube to keep it cool and to cool the jacket.

FITTING ALLOWANCES

86. The fitting allowances given in Table II represent good average practice for shafts from 1 to 8 inches in diameter. They also serve to suggest the allowances to be made on work of larger diameter. The plus sign indicates that the diameter of the shaft is to be increased by the amount of the allowance, and the minus sign indicates that the shaft is to be made smaller by the amount of the allowance. Judgment should always be used in determining the amount of allowance, as the values suggested in the table may have to be increased or decreased to suit the strength of the work and the use to which it is to be put.

BORING OPERATIONS

TAKING THE BORING CUT

87. Suppose a pulley 2 inches long is to be bored 1$\frac{15}{16}$ inches in diameter. The tool used is a boring tool, set as shown in Fig. 36. The tool is clamped rigidly in the tool post so that it lies parallel with the lathe V's and so that it will pass

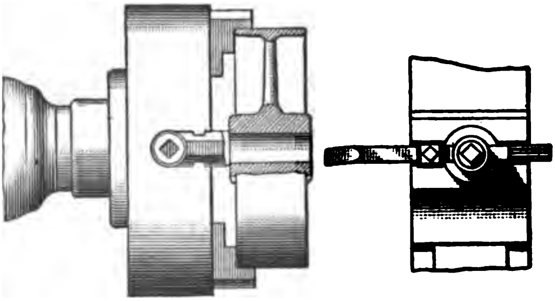

FIG. 36

through the hole in the work. It should be set as low as possible in the hole.

88. Roughing and Finishing.—Both roughing and finishing cuts are started at the front end. Roughing cuts should be as heavy as possible, but they can never be taken very heavy because of the spring of the tool. After the first cut the hole should be calipered to see whether it is being bored parallel. If it is found to be tapered, lighter cuts should be taken. Sometimes the hole may be made parallel by reversing the direction of the feed, which will start the cuts at the back end of the hole. If the hole is to be finished by boring, the last cut should leave a smooth surface; but if a reamer of the required size is available the hole can be bored $\frac{1}{32}$ inch too small and finished by running the reamer through while the pulley is still in the chuck.

MEASURING BORED HOLES

89. Use of Calipers and Gauges.—Greater skill is required for measuring the diameters of holes than for measuring outside work. The holes may be measured by the use of plug gauges, limit gauges, or inside calipers. When inside calipers are used, they may be set from a standard ring gauge, from a scale, or from a pair of outside calipers that have previously been set from a scale. When setting an inside caliper from a scale, one end of the scale should be held squarely against a block, as shown in Fig. 37, and the caliper adjusted to the line on the scale.

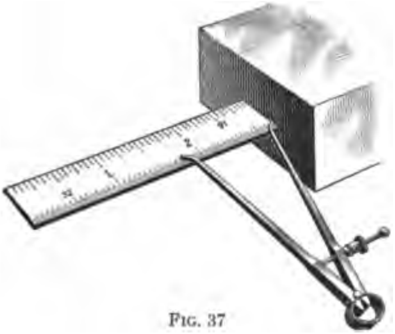

Fig. 37

90. When work is measured with inside calipers that have been set from outside calipers, there is chance for error in adjusting the outside calipers, in transferring the size to the inside calipers, and in the final measuring. It will be seen by reference to Fig. 38 that in order to measure accurately the calipers must be held in line with the axis *A B* of the hole. If the calipers were held in any other line, as, for example, *C D*, the hole would appear too large; for, with one point resting against the work at *b*, the other point *a* would be in the position *a'*. When the solid plug gauge is used for testing, extreme care is necessary. If the hole is the exact size, the gauge will enter only when its axis is held exactly in the line *A B*; because of this, the work is often bored too large, as insufficient care is used in making the trial.

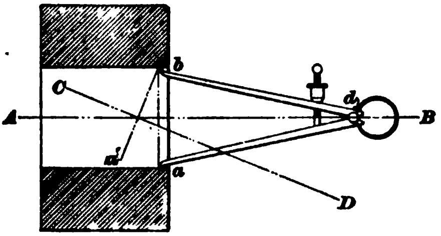

FIG. 38

If, in calipering a hole, it appears to be very close to size, a second cut may be run through without adjusting the tool deeper. A sufficient amount may often be removed by this second cut, its depth depending on the spring of the tool during the previous cut. When the hole is large enough to admit heavy tools, they should be used to avoid the spring as much as possible.

TAKING CUT WITH BORING BAR

91. Adjustment of Cutters.—After the work has been carefully set, and tested so that it is known to be correct, the cut is started at one end. One tool is used at first until a sufficient depth of cut is obtained and a short distance bored into the work. After this true place is turned, the other tools are carefully adjusted so that each does its share of the work.

92. Shape of Boring Tools.—The tools for the roughing cuts are ground round on the point, similar to the diamond point, and very little clearance should be given. The first roughing cuts are generally made deep, with a moderately fine feed. The finishing cuts are made with a very coarse feed. The finishing tool, therefore, has a broad cutting edge with a minimum of clearance.

93. Spring of Bar and Work.—It will be seen that the boring bar held between the lathe centers is limited in its power by the strength of the lathe center. When each of the four tools is doing its share of the work, the bar is well balanced in the cut, and the strain on the lathe centers is small. If the cut is very heavy on one side and light on the other, the opposite cuts will be unbalanced, the heavier cut tending to spring the bar away and into the lighter cut on the opposite side. This action will bring a great strain upon the centers of the lathe. If a surface to be bored is much out of true, it is best to true it by taking a number of light cuts to prepare the work for the finishing cut. Special boring mills, designed for this class of work, will do it better and more rapidly than the lathe. At the same time, the lathe is always at hand for special jobs when boring mills or boring lathes are not available.

94. Boring an Engine Cylinder.—The general scheme of using the traverse-head bar for boring an engine cylinder is shown in Fig. 39. The cross-slide is removed from the lathe and the work is set on blocking and clamped with bolts in its correct position. Considerable care should be taken in setting this class of work on the machine, to see that it is so set that all faces can be finished in their correct relation to one another and to correct sizes. The bar passes through the work, is held between the lathe centers, and is driven with a dog.

95. One of the various methods of operating the feed-mechanism is by means of the star feed, as shown in Fig. 39. A star wheel *w* is fastened to the end of the feed-screw, which revolves with the bar. A pin *t* is fastened in some convenient place so that for each revolution of the work it strikes one of the arms in the star wheel and gives it a partial revolution. When a coarser feed is desired, two or more pins may be arranged to act one after the other. By this means the feed-screw is revolved, and so gives motion to the head. Another method of revolving the feed-screw is to put a gear in the place of the star wheel. A second gear is fixed to the lathe center so that it gears with the wheel on the feed-screw. As the bar revolves, the gear and the feed-screw rotate about the fixed gear, thus revolving the feed-screw on its axis. If the gears are of the same size, the screw will make one revolution for each revolution of the bar. By varying the sizes of these gears, various rates of feed may be obtained.

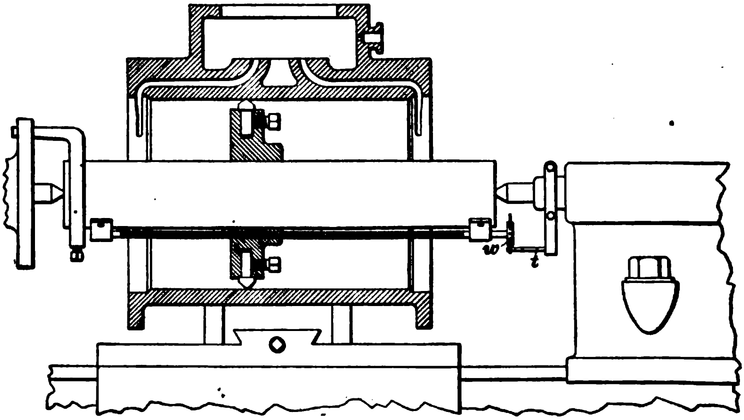

FIG. 39

The traveling-head bar is more desirable for large work than the bar with the fixed head, because the sliding-head bar need be but little longer than the hole through the work to be bored, and it is consequently stiffer. When the bar has a sliding head, the work does not need to be fastened to the carriage of the lathe, but may be bolted more securely to the lathe bed. This also adds to the rigidity of the work.

BORING TAPERS

96. Boring With Taper Attachment and Compound Rest.—Taper boring is often best done on the lathe. If the work is held in the chuck, the taper may be bored by using the taper attachment. The attachment is set in the same way as for taper turning, and the operation of taking the cut is the same as in boring cylindrical holes. When the holes to be bored are short or an abrupt taper is desired, the compound rest may be used. For some kinds of work, taper reamers are employed. They are held in the tailstock the same as the ordinary chucking tools.

97. Reaming Tapers.—Tapers may be reamed by a tool or tools inserted in the cutter head of a boring bar. The tools must be in the form of blades as long as the hole, and set so that their cutting edges form the required angle.

98. Boring Tapers With Traveling-Head Bar.—When the boring bar with the traveling head is used, a tapered hole may be bored in work fastened to the carriage or bed by setting over the headstock end of the bar. The bar is set over by clamping a false center *c*, Fig. 40 (*a*), to the face plate, and adjusting it at any required distance from the true center of the lathe. The amount that this center is to be set out of line may be estimated in the same way as the amount that the dead center is set out of line in plain taper turning. When the bar is thus set out of line, only one cutter point *p* can be used. It should be so set that when the false face-plate center *c* is at the front and at the same height as the dead center, the cutter point *p* is also at the same height.

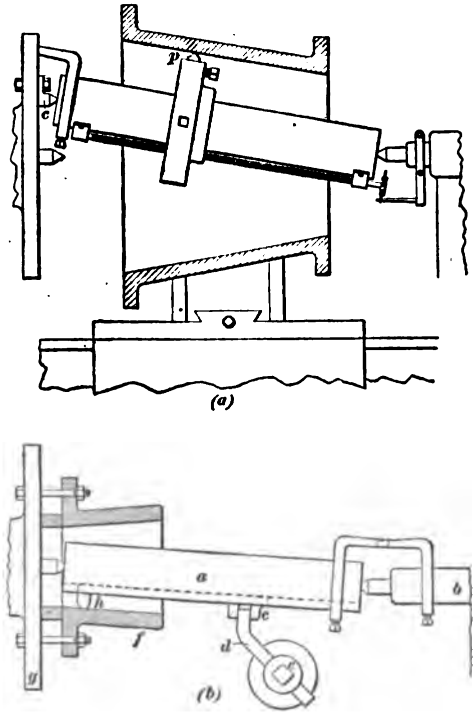

FIG. 40

99. Boring Tapers With Slotted Bar.—The slotted boring bar shown in Fig. 40 (*b*) may be used for either straight or tapered holes. The tool bar *a* is held on centers, and clamped to the dead-spindle end *b* so that it cannot rotate. Throughout its length it has a T slot or a dovetail slot that carries a sliding cutter. The cutter has lugs *c* that engage the end of a feeding piece *d* held in the tool post *e*. The work *f* may be clamped to the face plate *g* as shown. As the feeding piece *d* is fed along the lathe, it will force the sliding cutter fitting the slot to feed along the bar *a*, so that the cutting point *h* will bore either a tapered or a cylindrical hole, depending on the position of the dead center. The live center rotates in the stationary bar, and hence it should be hardened and supplied with oil. It is also necessary to feed the tool post in by means of the cross-slide as the cut advances, so as to prevent the lugs *c* from passing out of contact with the feeding piece *d*.

LATHE WORK

(PART 4)

LATHE OPERATIONS

TAPER TURNING

EXPRESSING AND FORMING TAPERS

1. Taper is expressed by the difference in diameter per unit of length, as $\frac{1}{8}$ inch to 1 inch, or 2 inches to 1 foot, meaning, in the first case, that if measurements are taken 1 inch apart on a taper, the difference in diameters will be $\frac{1}{8}$ inch, or, in the second case, if measured 1 foot apart, the difference in diameters will be 2 inches. It matters not how large a piece may be, provided this ratio of diameters is maintained. Fig. 1 shows a number of pieces of different diameters but all of the same taper. Their lengths are the same, and the difference of diameters at the two ends is constant.

2. Pieces of different lengths but of the same taper are shown in Fig. 2. The first piece, 1 inch long, has a difference of $\frac{1}{8}$ inch in diameter at the ends. The next piece, 2 inches long, has $\frac{2}{8}$ inch difference of diameter at the ends; the third piece, 4 inches long, has $\frac{4}{8}$ inch difference in diameter. If the piece were 12 inches long, the difference of diameters at the ends would be $\frac{12}{8}$ or $1\frac{1}{2}$ inches taper to the foot. It may thus be seen how taper expressed in one denomination may be reduced to another denomination. Thus, to reduce taper per

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foot to taper per inch divide the taper per foot by 12. To reduce taper per inch to taper per foot multiply the taper per inch by 12.

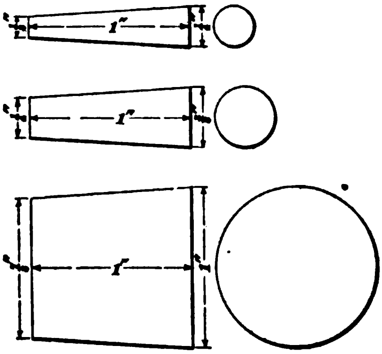


FIG. 1

3. Standard Tapers.—Tapers are often spoken of by numbers or by the names of particular makers, as, for example, the Brown & Sharpe taper of a given number, or the Morse taper of a given number. The Brown & Sharpe taper is supposed to be a taper of ½ inch to 1 foot, and the number of the taper indicates a particular diameter. The Morse taper was intended to be ⅝ inch to 1 foot, and the numbers indicate different sizes. Unfortunately, the first standards were slightly inaccurate, and consequently the different numbers of Morse tapers are not the same as originally intended and only the tapers Nos. 0 and 7 are exactly ⅝ inch to 1 foot. The taper of pipe threads is ¾ inch per foot, which is called standard taper in some shops.

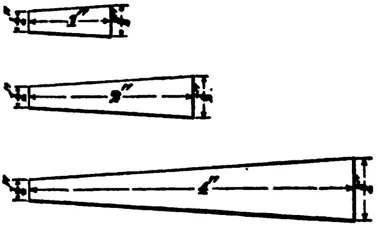


FIG. 2

4. Methods of Turning Tapers.—There are four common ways by which a taper may be turned. The dead center may be set out of line with the live center; a lathe provided with a special taper attachment may be used; a special turning lathe in which the headstock and tailstock may be set at an angle to the line of tool feed-motion may be employed; or the taper may be turned with the aid of a compound rest. The first method is applicable to outside turning, although by the use of a steady rest it may also be made applicable to boring. Many sleeves and collets are bored in this way. The other three methods may be used for turning and boring.

SETTING OVER THE TAILSTOCK

5. Construction.—The tailstock of a lathe is so constructed that the spindle may be moved to bring the dead center either exactly in line with the live center for parallel turning or out of line with the live center for taper turning. Fig. 3 shows an end view of a tailstock. The base *a* is fitted to the lathe bed. The top *b* is fitted accurately to the base *a* and may be moved toward either the front or the back of the lathe. The top part *b* is moved by turning the adjusting screw *c* at the front. When it is desired to turn a taper, the tailstock is unclamped by loosening the nut *d* that clamps it to the bed and the dead center is moved out of line an amount that has been previously calculated or found by trial to be correct.

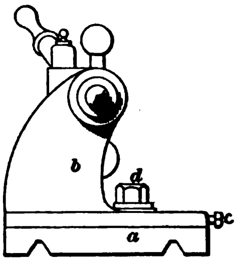


FIG. 3

6. Amount of Set-Over.—The amount that a center should be moved to turn a given taper can be easily calculated. Suppose that it is desired to turn a taper ½ inch to the foot on the piece shown in Fig. 4. This means that in 1 foot of length the difference of diameters is ½ inch, and as the piece is 1 foot long, it will be necessary to move the dead center out of line and toward the front of the machine one-half of this half inch, or ¼ inch. It must be understood in turning that if a cut ¼ inch deep is taken the diameter is reduced ½ inch. Moving the dead center toward the tool ¼ inch is

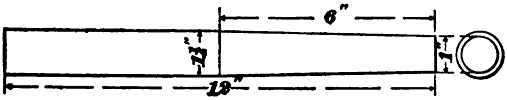


FIG. 4

equivalent to taking a shaving, or cut, $\frac{1}{4}$ inch deep. The amount that a center is set out of line may most easily be measured by moving the two centers close to each other and measuring from point to point with a scale, as in Fig. 5, or by means of a scale on the tailstock, as shown in Fig. 6.

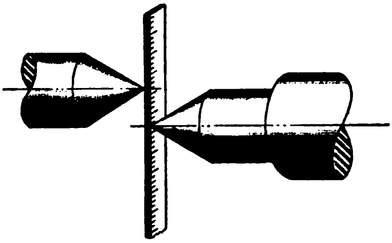


FIG. 5

7. Suppose that in the piece shown in Fig. 7 the taper is $\frac{3}{4}$ inch to 1 foot and that the piece is 10 inches long. If the piece were 12 inches long, it could at once be estimated that the center should be set out of line $\frac{3}{8}$ inch; but as the piece is less than 12 inches long, $\frac{3}{8}$ inch would not be correct, as it would turn the taper too blunt. The taper per foot is reduced to taper per inch by dividing by 12. Dividing $\frac{3}{4}$ by 12 gives $\frac{3}{4}\times\frac{1}{12}=\frac{3}{48}=\frac{1}{16}$ inch; $\frac{1}{16}$ inch to the inch is therefore equal to $\frac{3}{4}$ inch to the foot. Multiplying the total length of the piece between centers by 10, $\frac{1}{16}\times 10=\frac{10}{16}=\frac{5}{8}$ inch, the taper in a piece 10 inches long. As the center is set over half the amount of the taper, divide $\frac{5}{8}$ by 2, which gives $\frac{5}{16}$ inch, the amount that the center should be moved out of line.

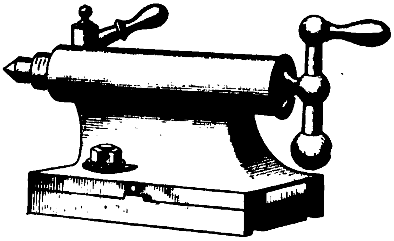


FIG. 6

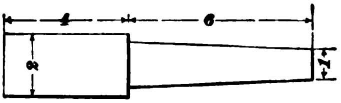


FIG. 7

8. **Setting by Notches.** When the taper per foot is not given but the diameters and the distance between them are known, the notch method may be used. Suppose that a piece as shown in Fig. 8 is to be finished. Notches are first cut in the stock, as shown at *a* and *b*, Fig. 9. One notch is cut to the diameter of the taper at the small end. The second notch

is cut to the correct diameter at the large end. From these diameters, measurements are taken for setting the lathe, as will be shown later.

9. The work is kept between the centers after notching and the tool held in the tool post, the same as for cutting the notches. The dead center is set over an amount estimated by judgment. The tool is then moved opposite one notch of the work, as at *a*, Fig. 9, and the distance from the point of the tool to the bottom of the notch is measured. The tool and carriage are then moved opposite the second notch *b*, and the same measurement is taken. If the measurements are alike, the work is correctly set; if not, the dead center must be adjusted until they are the same. After each adjustment of the tailstock, the distance must be measured from each notch to the tool point. It is not right to measure with the tool in position *a*, and then adjust the tailstock until the measurement at *b* is the same, for it will be seen that in changing the measurement at *b* the measurement at *a* will also change, although not so rapidly.

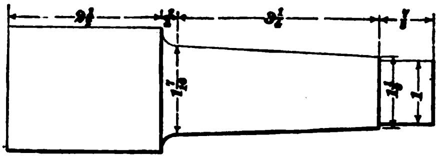


FIG. 8

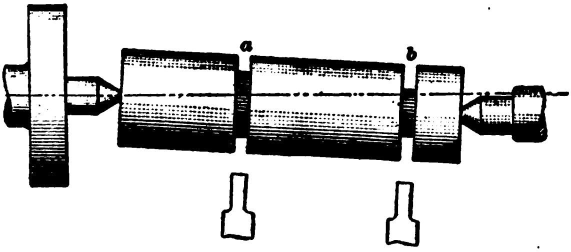


FIG. 9

Various methods are employed for taking the measurements from the work to the point of the tool. An ordinary scale or a pair of inside calipers may be employed. When calipers are used, it is better to use the butt end of the tool, or some flat surface, as it is easier to measure between surfaces than between points.

10. Caliper Tool.—A still better way is to have a special caliper tool, as shown in Fig. 10. It consists of a shank *b* like an ordinary lathe tool, to the end of which is pivoted a pointer *p*, which can be moved like the leg of a caliper. The tool is clamped to the tool post and adjusted so that the rivet *e* on which the pointer swings is at the same height as the axis of the work. When testing the work, the pointer is brought opposite one of the notches and the tool is adjusted by means of the cross-feed screw until the end of the pointer just touches the work, as shown. The nurled knob *a* is connected with the pointer and is used for moving it in calipering. After the tool is adjusted for one position, the pointer is dropped so that it can be moved to the other position, where it will at once indicate whether the work is correctly set or not.

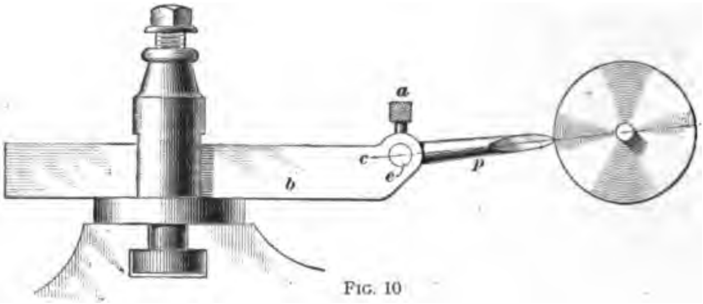


Fig. 10

11. Setting by Turning Parallel to Two Diameters. Sometimes tapered work is set by turning to two diameters, as shown in Fig. 11, the work being turned to the smallest diameter of the taper up to its beginning, and then from this point to the head of the taper the work is turned to the largest diameter of the taper, as shown. After this, the tool may be set to the large and small diameters *a* and *b*, as in the case of setting by notches. The advantage of this method is that a large portion of the stock is removed

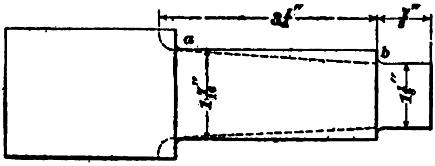


Fig. 11

while the work is between centers that are in line and the centers of the work fit perfectly.

12. Setting With a Model Piece.—When a model taper has been furnished, the lathe may be set directly from it. The model is put between the lathe centers, and the dead center is so adjusted that the measurements from the point of a tool in the tool post to the taper model remain constant as the carriage and tool are moved along its length. When close measurements are desired, the tool, or, better, some article with a rounded end, is brought close to the model, and at the height of the center so that it loosely pinches a piece of tissue paper. The tool and the paper are moved along the length of the taper and the setting is tested at various places by pulling the paper. If the paper slips between the tool and the taper model with about the same pull at all places, the setting is correct.

OBJECTIONS TO SETTING OVER OF DEAD CENTER

13. Wear of Centers.—When the dead center is set over considerably, as shown in Fig. 12, it will be seen that the dead center touches the work at only two points. This is objectionable, as the work rotates about the dead center, and there is a tendency to wear away both the center holes and the lathe centers. Much wear would result in a shape as shown in Fig. 13. The front side of the point of the center is worn away, a groove is formed at the back, and the center hole is worn into a bell shape. The live center revolves with

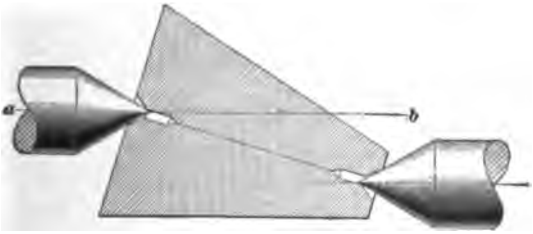


FIG. 12

the work, so that the wearing action between it and the center is somewhat different. On the dead center the work has a rotating motion, but on the live center it has a reciprocating motion. The result is that the live center is worn evenly all around, and the center hole is worn to about the same shape as the dead-center hole.

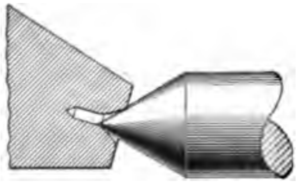


FIG. 13

14. This wear on the center holes is very objectionable. It makes it difficult to turn a true taper, and if a part of the work has been turned true and parallel, it will be found to run untrue on the worn center holes. The result is that after a taper has been turned, the tapered part and the parallel part do not run true with each other. Besides, if the lathe centers become much worn, it will be necessary to grind them before parallel or true work can again be turned.

15. Different Tapers for Different Lengths of Work. When it is desired to turn the same taper on a number of pieces of different lengths, it will be found that the center must be adjusted or reset for each length of work. When the lathe is adjusted to turn a given taper or work of a particular length, it will be found that if the work is a little longer or shorter, the taper will be changed. Suppose that, in Fig. 14, *a b* represents the line of lathe centers for turning parallel work. Assume that the dead center is set out of line $\frac{1}{4}$ inch, as shown by the line *c d*. Any piece that may be turned with the dead center thus set will have a difference of diameters

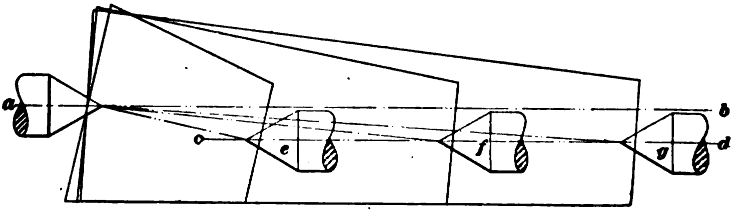


FIG. 14

at its ends of ½ inch. If the piece is 1 inch long, so that the dead center is in position *e*, the taper will be ½ inch to the inch. If the piece is 2 inches long, so that the dead center is in position *f*, the taper will be ½ inch to 2 inches, or ¼ inch to the inch. If the piece is 3 inches long, so that the dead center is in position *g*, the taper will be ½ inch to 3 inches, or 2 inches to the foot. These three tapers may be compared by reference to the outlines. It is evident that any slight difference in the distances between centers in turning two pieces of work will make a difference of taper that can readily be detected when fitting work. If in two pieces of the same length, one has much deeper center holes than the other, it will allow the lathe centers to come closer together, which will cause a slight error in the taper that may have to be corrected in the final fitting.

16. The amount of taper that can be turned between centers by setting over the center is limited by the total length of work and the amount of adjustment possible in the tailstock. Suppose the greatest amount of set-over in the tailstock is 2 inches. This will make a difference of diameter at the ends of the work of 4 inches. If it is desired to turn a taper of 1 inch to the foot, the greatest length of shaft on which it could be turned is 4 feet, and if the shaft or work should be longer, it would be necessary to use some other method of turning the taper.

TURNING TAPER

17. Use of Compound Rest.—When the taper is very abrupt, such as 1 inch to the inch, it can be turned best by means of the compound rest, shown in Fig. 15. It consists of an extra slide for carrying the tool block, which is mounted in the place of the tool block on the ordinary saddle. This extra slide rests on a circular base and can be so rotated and set that the motion of the tool block may be in a line at any angle with the regular cross-feed. The base of the compound rest is usually graduated with degrees, so that it may easily be set at any desired angle. When the angle in degrees of a taper is not known, it may be found by making a drawing of the work.

18. Example.—Suppose that it is desired to turn the piece shown in Fig. 16. If the drawing has been accurately made, the angle may be measured with a bevel protractor; if only a sketch with dimensions is given, the angle may be laid off as follows: Draw two lines *a b* and *c d*, Fig. 17, at right angles to each other, intersecting at *o*. On *a b* lay off from *o* a distance of 8 inches, equal to the distance between the given diameters. On *c d* lay off 7 inches, equal to half the difference of diameters, or equal to the difference of radii. Draw a line through these two points. If a protractor is at hand, the angles may be measured; if not, a bevel may be set equal to the angle *y*. With the bevel, the compound rest may be set at the proper angle by using it as shown in Fig. 15. The beam of the bevel is held against the face plate while the compound rest is swung to the angle indicated by the blade of the bevel. This method of setting the compound rest is also used when boring tapered holes. The bevel is used also to set a compound rest that is not graduated.

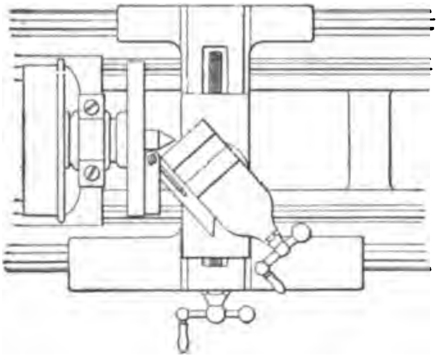


FIG. 15

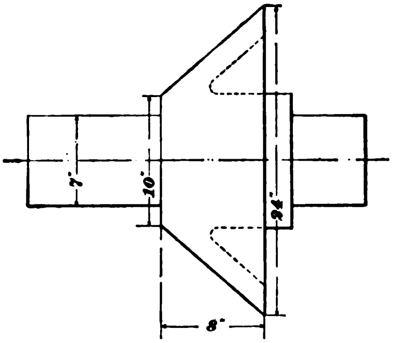


FIG. 16

19. Use of Two Feed-Motions.—Another method of turning tapers is to use the two feeds at once. The longitudinal feed is thrown in and the tool may be fed crosswise by hand. This method is used for roughing steep tapers rapidly.

20. Position of Tool.—The operation of turning a taper after the machine has been set is similar to that of turning a plain cylinder. The difference will be found in the manner of setting the tool. This exception is of sufficient importance to warrant the statement of the following rule: The point of the tool for turning a taper should be at the same height as the axis of the work. If the tool is set above the center, the large end of the taper will be turned too small, and the sides will be curved inwards instead of straight.

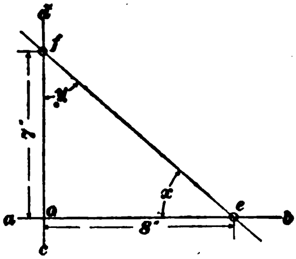


FIG. 17

TURNING AND FITTING THE TAPER

21. Methods of Turning and Testing.—A taper is turned by the set-over method by setting the center over a distance judged to be correct. A tool is set to the height of the center and a roughing cut is taken over the taper. After the roughing cut has been taken, and before the tapered piece is near the finished size, it should be tested in the piece it is intended to fit. The taper is carefully placed in the tapered hole and first tested by the sense of feeling. If one end is much too small, as at *c*, Fig. 18, it can be detected by rocking the work in the hole. The plug will just fill the hole at the outer end *a*, and though the imperfect fit cannot be seen, it can easily be felt. In case the indications are that the dead center was moved too far out of line, it should be moved

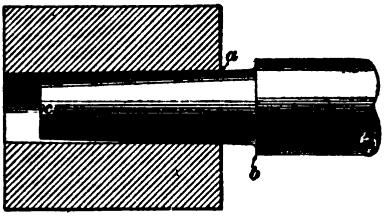


FIG. 18

back a very slight amount and another cut taken over the work. After this cut, the work should be tested again, and if there is no perceptible wabble the fit may be tested still more closely by drawing three chalk lines along its length. The work is then placed in the hole and a turn or two given in a direction opposite to the motion it had in the lathe. On removing the work, it will be seen that the chalk has rubbed off, and is black at either one end or the other, depending on which end was too large.

22. The tailstock is adjusted again, and a light cut is taken over the taper. The chalk marks are drawn along the taper and it is tried in the hole again. If the chalk is rubbed off evenly the whole length it indicates that the setting is correct. The taper is then turned to size by one or more light cuts. The size should be such that the taper will go in nearly as far as required. The lathe is speeded up and the taper is filed evenly all over with a smooth file to remove the tool marks. Chalk marks are made along it again, and it is tried in the hole by being given a turn or two backwards. The chalk will be rubbed off the high parts of the taper, and a smooth or a dead-smooth file should be employed to touch off these high spots. The file should be clean and used with a light, even pressure. A further test will usually show that the bearing has been improved. The tests and corrections are repeated until the chalk is rubbed off evenly the whole length, when the taper will be a practical fit.

23. Prussian-Blue Marking.—In fine fitting, the thickness of a chalk line is sufficient to make an error of some importance, so a substitute is used. One half of the tapered piece along its length is coated very thinly with Prussian-blue marking, applied with the finger, and nearly all rubbed off, just enough being left to give it color. The work is then tested in the hole or gauge, and a turn given to it. If the marking is evenly distributed along the taper, it indicates a perfect bearing.

RADIAL FACING

FACING OF REVOLVING WORK

24. When a true flat surface is turned in a lathe, on work held in a chuck, on a face plate, or between centers, the operation is called **radial facing**; for example, squaring up the ends of a piece of work held between centers is radial facing.

25. Essentials in Radial Facing.—There are two important points in all facing. First, all end play of the lathe spindle must be taken up. Second, the carriage must be clamped on the V's, which prevents the tool from moving away from the work.

26. Tools Used and Their Shapes.—Tools for radial facing do not need so great a clearance angle or front rake as when cylindrical shapes are turned. In shape, the tools for radial facing resemble planer or shaper tools, especially when they are used for facing from the outside toward the center. A large variety of tools can be used for radial facing, and in most cases a bent tool is preferable, because in the tool post it can be held closer to the cutting edge, thus giving greater stiffness.

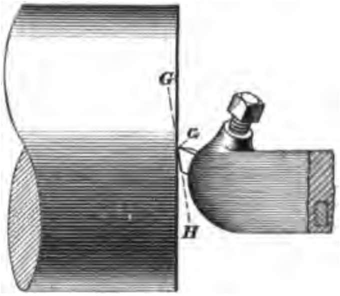


Fig. 19

27. In Fig. 19 is given a front elevation of a tool presented to the work for radial facing, the front rake being shown by the line *G H*. The tool point *a* is placed about level with the center of the work. Fig. 20 gives a plan illustrating how the same tool should be set. The tool should make an angle of from 30° to 45° with the face of the work, and the cutting edge should be presented to the work as indicated by the line *E F*. The type of tool shown should be fed from the outside toward the center, the tool being set at the same height as the center of the work. The tool may be fed either by hand or by power feed. For finishing radial surfaces, the side tool may be employed, or a special square-nosed tool may be used. The square-nosed tool has the advantage that it can be fed in either direction. If the feed and the cut are heavy, care must be taken that the tool does not swing into the work.

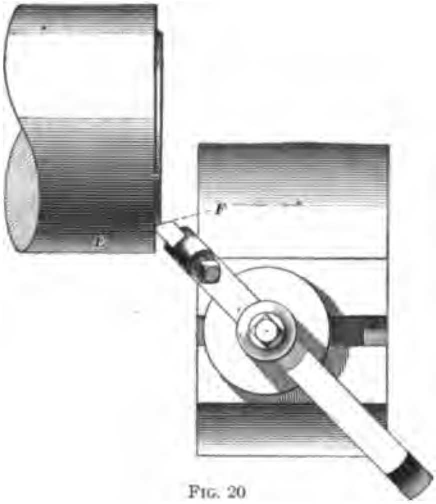


FIG. 20

28. Cutting Speed. In radial facing, the cutting speed of the tool will vary according to the diameter of the work at the point where the tool is operating, the number of revolutions per minute remaining the same; hence, it is evident that, as the tool advances toward the center, the cutting speed will decrease. For this reason, on large surfaces, it is advantageous to speed up the lathe as the tool advances toward the center.

FACING OF STATIONARY WORK

29. Position of Work.—When the work to be operated on is so large that it cannot be swung on the face plate, it must be blocked up to the proper position and bolted to the carriage or lathe bed securely, so that there will be no chance of its moving during the facing. It is faced by means of a rotating tool or cutter.

30. Facing Arms.—For facing the ends of cylinders a facing arm is used, as shown in Fig. 21. The arm is fastened to, and rotates with, the boring bar. On one side is fitted a tool block *a* that slides on a guide, and that carries the cutting tool *b*. Feed-motion is given by means of a screw operated by the star wheel *c*, which is made to rotate partly for each revolution of the bar. In this way, the tool is fed entirely across the face of the work. When a facing arm is not at hand, a cross-slide of some sort is fastened to the face plate of the lathe. Very often the compound rest is so fastened to the face plate that the slide may be used for feeding a tool across the face of the work.

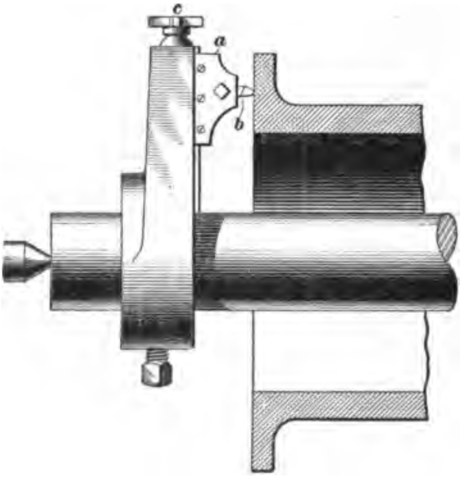


FIG. 21

31. When a piece of work held either in a chuck or on a face plate is to be bored and faced, it is best to do the facing first, or at least to take a roughing cut before doing the boring. A better chance is thus given to start chucking tools and a better edge is furnished for calipering the hole; also, when facing, the tool has a greater leverage on the work, and hence a greater tendency to displace it. For these reasons, all facing and outside rough turning should be done before boring.

TURNING LONG WORK

32. Steady Rest.—When long shafts are to be turned, it is necessary to support them along their length; otherwise, they will bend and vibrate so that it will be very difficult to take a cut from them. Fig. 22 shows a steady rest that is supplied with engine lathes. When in use, this rest is bolted to the top of the lathe bed at a place where it is desired to support the shaft. The rest is made in two parts, with a hinge *a* at the back and a latch or clamp *b* at the front. After the steady rest is clamped on the bed, the latch is unclamped, the top half turned back, and the jaws moved so far from the center that they will not touch the shaft. The shaft can next be put in the lathe between the centers. The top half is then closed and clamped in place. If the shaft is true, the jaws *c* may be adjusted so that they just touch it.

33. The steady rest is adjusted by sliding the front bottom jaw *c* up so that it is in light contact with the shaft, and running up the setscrew *d* so that it is in like position with the jaw. The lower back jaw is then adjusted in the same manner. The pressure of the setscrews must be so light that neither jaw will spring the work in the least. The top is then closed and clamped securely. The top jaw is brought in contact with the work and the top setscrew is adjusted to it, which will leave the shaft an easy running fit in the rest. The clamp screw in each jaw is then tightened securely and each setscrew is tightened lightly. If the work heats and runs tight in the rest, it is relieved by slightly unscrewing the clamp screw holding the top and the bottom together. The jaws should be oiled where the shaft turns on them.

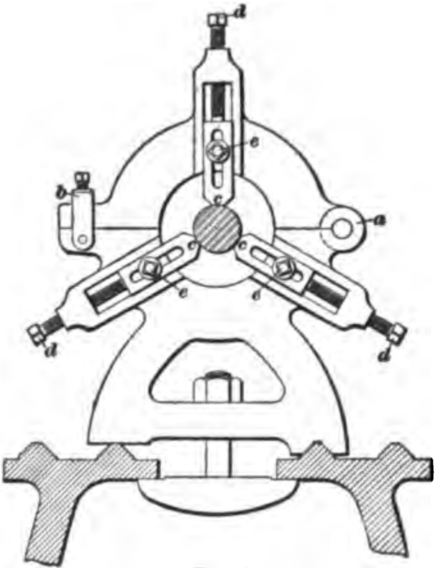


Fig. 22

34. In Fig. 23 is shown a method of holding a bar when it is desired to operate on the end for boring or turning. In adjusting a steady rest, the bar is held by one end in the chuck and adjusted to run true, and the other end is supported on blocks of wood at a height equal to that of the dead center.

The steady rest is moved very close to the chuck and the jaws are moved to touch the bar. Afterwards, the steady rest is opened by turning back the top, but without changing the adjustment of the jaws. It is then moved down the bar, and clamped in the desired place. By this method of adjusting the jaws, the work is held in line with the headstock spindle. This method of supporting work is often used for very large pieces, and, when necessary, very large and heavy steady rests are used.

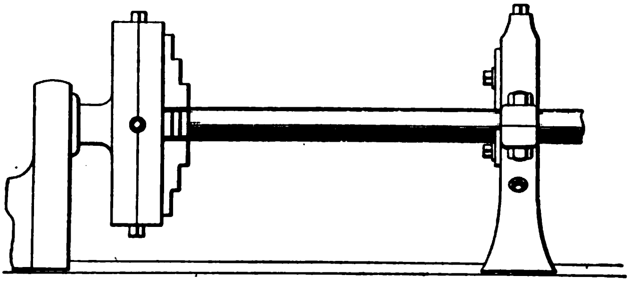


FIG. 23

35. The forging for a large gun is usually operated on while one end is supported in and driven by a chuck, and the body of the piece is upheld by one or more steady rests of an especially heavy design. Fig. 24 illustrates one of them supporting the inner tube for a 12-inch gun, *a* being the tube and *b* a large cannon drill used for boring the inside of the tube. In gun work, the roughing and finishing tools are specially designed drills and reamers, and the cutting speeds are very slow, it having been found that speeds exceeding 6 or 8 feet per minute with carbon-steel tools are usually unprofitable, as they will cause excessive wear and breakage of the tools.

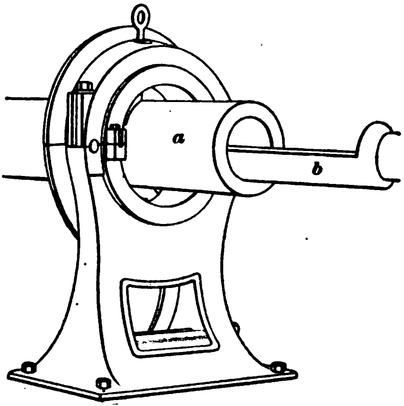


FIG. 24

36. Spotting of Shaft.—If the shaft does not run perfectly true, a spot that does run true must be turned on it, and the jaws of the steady rest must be adjusted to the spot. If the steady rest were adjusted to a place that did not run true at first, it would be found that after it was adjusted, the shaft would appear to run true and would continue to do so until the jaws were again loosened, when the shaft would spring to its natural shape and wabble as before. When a shaft is to be spotted for the steady rest, a very fine, light cut of any diameter is made to give the jaws a fair bearing.

37. If the shaft is quite long and it is desired to put the steady rest near the middle of the shaft, it may be found that the shaft cannot at once be spotted in the middle because of its extreme flexibility. Cuts near the end of the shaft, where it is better supported by the lathe centers, may be taken. In such a case, a cut would be taken near the dead center and a spot made. When the shaft is thus spotted, the steady rest may be adjusted to this place and the second spot turned farther along. In this way the spots may be moved along the shaft until the middle is reached.

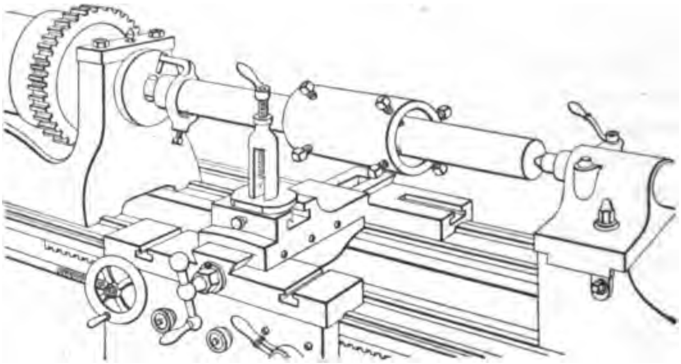


FIG. 25

38. Cat Head.—On some classes of work, it is desirable to use the steady rest on a part that does not run true, and it is not desirable to spot the place on the shaft. In such a case, a device called a cat head is adjusted on the shaft. A cat head is a collar that fits loosely over the shaft at the place where the steady rest is to be set, and is there clamped on the shaft by a number of setscrews, as shown in Fig. 25. By varying the adjustment of the setscrews at the ends, the cat head may be set to run true. This device may be used on square work or on any piece of work that does not have a true surface or that cannot be spotted for a steady rest.

39. After the cat head has been set, the jaws of the steady rest may be adjusted to it the same as to a larger shaft. In the case of the slender shaft just mentioned, the cat head may be used instead of making the series of spots from the end. If the shaft is long, it may be necessary to use two or more steady rests. When the tool and carriage have fed up to the steady rest it must be moved to another position to allow the cut to pass. It is difficult to turn long shafts and have them remain straight, even if the spots are turned with great care. When the shaft is rolled, its surface is more or less under tension, and, as it is turned, this tension is removed, thus allowing the shaft to spring so that the spot that was turned true when the shaft was rough is untrue after it is turned.

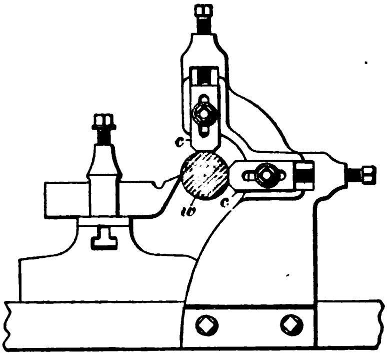


FIG. 26

40. Follower Rest.—Another method of supporting shafts while being turned is by the use of the follower rest, as shown in Fig. 26. This rest is bolted securely to the carriage and travels with it. When it is used, a cut of the desired diameter is started at the end of the shaft. As soon as a spot is made true, the two jaws *c* are carefully adjusted to the work *w*. As there is a tendency to spring the shaft away from the tool, two jaws are sufficient to support the work.

41. Solid Bushings.—Another method of supporting the work is by means of the follower rest supplied with bushings, so that as soon as the end of the shaft is turned, it enters a rigid bearing. Such a follower rest is shown in Fig. 27. Bushings *b* bored to different diameters are used for different sizes of shafts. This style of follower rest gives a very perfect support for the shaft. When used, the tool is set slightly in advance of the follower. The closer the tool is set to the follower rest, the less danger there is of its chattering.

42. Special Shafting Lathe.—When much shafting is to be turned, a regular shafting lathe is used. These lathes have very long beds and the carriage is fitted with a shafting turner, which consists of a follower rest with bushings to fit around the shaft, similar to that shown in Fig. 27. It also has two, three, or four tool slides, so that an equal number of tools may be used to cut at once. When used, two or three roughing tools precede and one finishing tool follows the rest. The shaft is thus roughed and finished at one cut.

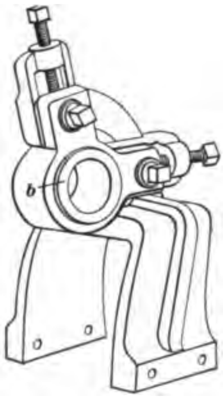


FIG. 27

43. Straightening Machines. After the shafts are turned, they are apt to be crooked from the release of the surface tension. They are straightened on a regular shafting straightener, which consists of a number of conical rolls so arranged that, as the shaft is revolved and drawn between them, it is bent and straightened.

44. Straightening Small Work.—A special straightener is not always necessary to straighten a shaft. Small straightening presses may be used for bending a crooked shaft to make it straight. These straightening presses are so constructed that the shaft to be straightened rests on two supports from 1 to 3 feet apart, depending on the size of the straightener. An arm projects from behind the machine, midway between the points of support, and over the shaft in such a way that a vertical screw may be used for pressing the shaft down. The shaft to be straightened is supported between the centers of the lathe, and while revolving slowly is marked with chalk on the high side. It is then removed from the lathe to the straightener and bent sufficiently to make it straight. A number of trials may be necessary to make the shaft run true. If the bend is a short kink, then all the straightening should be done at that place; but, if the original crook is a long sweep, the work should be straightened by a series of applications of the press along the work.

45. The press is sometimes supported on wheels and set directly on the lathe bed. After the work is tested, the press is moved along the bed to the crooked place on the shaft, and, after the lathe centers are loosened, the machine is used for straightening the work. If a press is not at hand, a shaft may be straightened after marking by taking it from the lathe and resting it on two solid blocks of wood, with the marked part up between the blocks. A third block is placed on the shaft between the supporting blocks, and is struck a blow with a hammer or sledge. Care must be taken not to deliver too heavy a blow, or the work will be more crooked than before.

46. Sometimes, when the proper straightening devices are not at hand, slender work may be straightened between the lathe centers; but such practice injuries the lathe and should not be used except in special cases. The work is revolved between the lathe centers and the high side marked. A bar or lever is then put over a tool in the tool post and under the work in such a way that when the lever is pushed down by hand the work will be sprung up. By turning the work so that the marked part is down, it can be so sprung that, after a number of trials, it will run quite true. If the bend is long and uniform, it can be straightened by simply bending or springing the bar as just indicated. If the shaft appears to have a short bend, while either side of the bend appears to be straight, this short bend can be taken out by springing up the shaft with the lever, as described, and striking a few blows with the hammer on a piece of sheet brass or copper placed on the top of the shaft on the bent part. The hammering should be light at first, or the bar will be bent as badly as it was before, but to the opposite side. This hammering has a peening action that tends to stretch the shaft slightly on the side struck.

47. Straightening Lead Screws.—Peening is sometimes used for straightening large or long lathe lead screws after they have been threaded. A special tool is used for peening between the threads, as shown in Fig. 28. It is made thin at its edge, so that it will go loosely between the threads down to the root, and is concave, so that it fits around the screw for a short distance. The screw is tested and the untrue spot located. The high part is turned down and sprung up with the lever at the bent place, and, while held in this sprung position, a few of the spaces between the threads on the top side are peened with the peening tool and a hammer. With some skill, a screw that is badly bent may be quickly straightened. This method of straightening screws will not do when the pitch of the lead screw must be accurate, because it will stretch the screw slightly. For ordinary purposes, however, the stretching of the screw caused by slight peening would scarcely be perceptible. The most accurate lead screws are always straightened without peening, and the finishing cut is taken on the sides of the threads without disturbing the core.

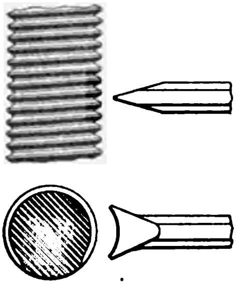


FIG. 28

TURNING WITH A ROTATING TOOL

48. Occasionally, work must be done that requires the turning of a trunnion, or projection, on a large and heavy casting. If such a casting were placed in the lathe and rotated on centers, a very large lathe would be required to do the work. Fig. 29 illustrates a method by which this difficulty has been successfully overcome. The casting *b* is long and heavy and is supported at one end on a regular carriage *a*, and at the farther end on a special carriage not shown in the illustration. The work requires that the portions *c*, *d*, and *e* be turned to three different diameters. They are roughed by a tool attached to the special arm *f* on the face plate *g*. After the three diameters have been roughed out, the face plate *g* is unscrewed from the spindle and the attachment *h*, shown in the foreground, is substituted for it. This attachment carries hollow mills, as shown at *i*. The mill shown at *i* is intended for finishing the portion *c*, and after this portion is finished the mill shown at *j* is substituted to finish the portion *d*, and the mill shown at *k* to finish the portion *e*. The tool or mill always revolves at the same distance from the face plate or end of the spindle, the work being fed into or past the revolving tool by means of an ordinary feed on the carriage *a*.

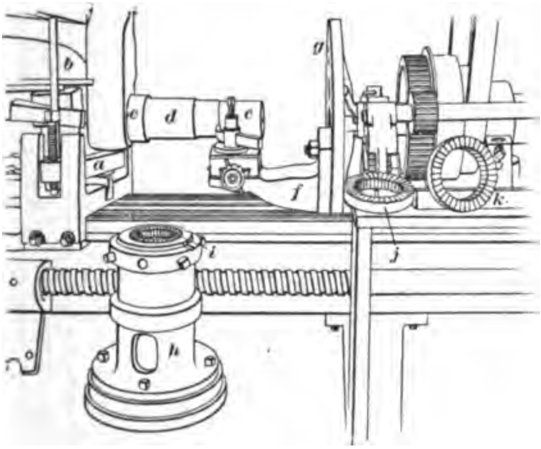


FIG. 29

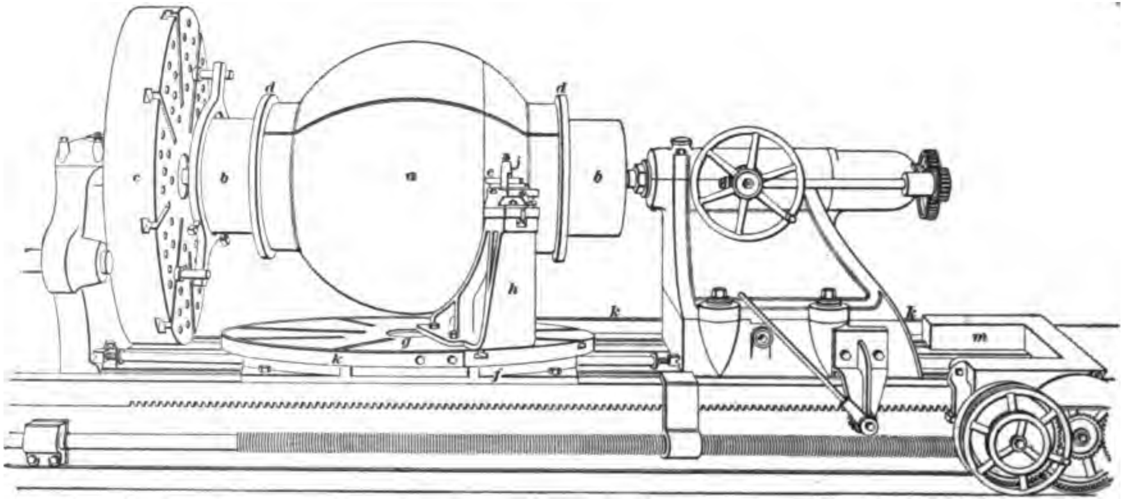


FIG. 30

SPECIAL LATHE WORK

49. Ball Turning.—To turn balls in engine lathes, special appliances are necessary to regulate the feed. Fig. 30 shows such an arrangement applied to turning a large cast-iron ball *a* for an engine bearing. The mandrel *b* is supported on the lathe centers and driven by drivers on the face plate *c*. The ball is made in sections that are clamped to the mandrel by the iron bands *d*. The tool *e* moves in a circle around the work while the work rotates with its axis as a diameter of the circle in which the tool revolves. On the stationary table *f* the rotating circular table *g* is pivoted and carries with it the upright *h* that supports the tool post *j* and the tool *e*. At *k*, on the rotating table *g*, is a wrought-iron band that is fastened by capscrews at one end to the table. The other end is fastened to the lathe carriage *m*, and as the lathe turns the carriage is fed away from the tailstock toward the end of the lathe, drawing with it the band *k* and thus rotating the table *g* about its axis. As the work rotates in the lathe the tool moves around it in a circular arc, so that it is always at the same distance from the point on the axis that is the center of the sphere. On smaller work, a similar method is

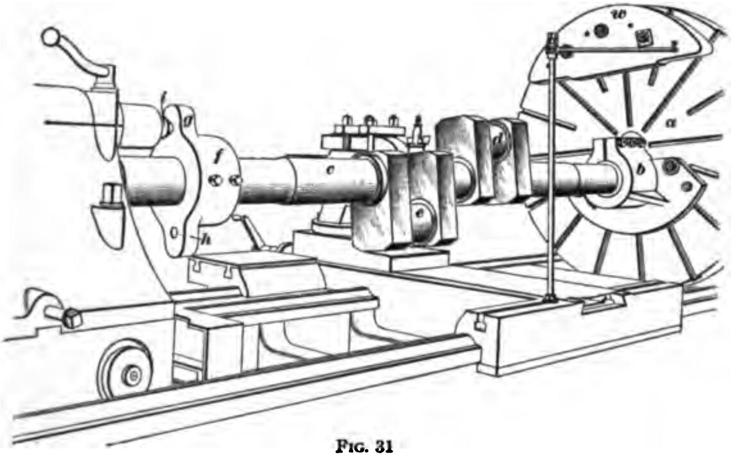


FIG. 31

used; but the tool is carried on a table that has a worm-wheel fastened to it and is rotated by a worm. The worm may be operated by hand or from the feed-mechanism of the lathe.

50. Turning a Crank-Shaft.—One method of holding a large crank-shaft in a lathe while turning its crankpins is shown in Fig. 31. The crank-shaft *c* is so fastened that the center line of the crankpin *d* coincides with the center line of the lathe spindle. The clamp *b* that holds one end of the shaft is fastened to the face plate *a*, and the clamp *f* that holds the other end of the shaft has an offset center *g* in which the dead center *i* of the lathe fits. The counterweight *w* is fastened to one side of the face plate to balance the weight of the shaft. The crankpin *d* is turned while the shaft is held in the position shown. To center the shaft so as to turn the pin *e*, the end of the shaft next the tailstock must be blocked up, the clamp *b* loosened from the shaft, and the dead center removed from the clamp *f*. The shaft is then rotated till the center *h* on the clamp *f* comes to the dead center, when the center is moved into *h* and the clamp *b* made fast to the shaft. The centers *g* and *h* on the clamp *f* hold the same relation to one another and to the shaft as do the center lines of the crankpins. When the shaft is fastened in this position, it is ready for turning the crankpin *e*.

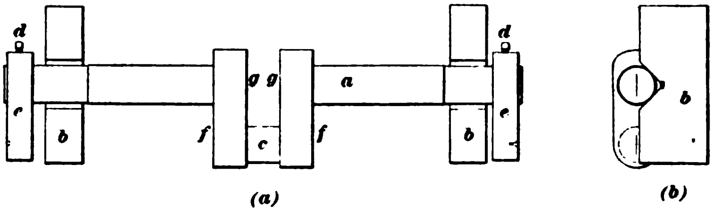


FIG. 32

51. Laying Out Centers for Turning Crank-Shafts. The process of locating and preparing the centers for a solid crank-shaft is illustrated in Fig. 32 (*a*) and (*b*). The crank-shaft *a* is centered, and the ends are turned to size for a short distance, to receive the centering blocks *e* and to fit the

V blocks *b*. The shaft is then placed on the **V** blocks on a surface plate and the centering blocks are fastened to the finished ends in line with the crank-arms. The centering blocks are bored to a good fit on the turned ends of the shaft, and are fastened, so that they cannot slip, by the setscrews *d*, or in some cases by keys. The shaft is then rotated until the center of the crankpin is the same distance above the surface plate as the center of the shaft, and is blocked in this position. A horizontal line across the end of the shaft through its center and across the centering block *e* is then drawn with a surface gauge. The center of the crankpin *c* is somewhere on this line and can be laid off with the scriber or a pair of dividers by taking a length equal to the distance from the center of the shaft to the center of the crankpin and laying it off from the center of the shaft. When the centers are located on both ends, they are drilled and countersunk. The shaft is then ready for the lathe and all the lathe work can be completed on the shaft itself, on the crankpin, and on the crank-arms. The shaft is turned and the sides *f* of the crank-arms are faced when the work is on the centers in the ends of the shaft. The work is then moved to the centers for the crankpin *c*, which are laid off on the centering blocks *e*. The crankpin is now turned, and the sides *g* of the crank-arms are faced. If the crank-arms are circular disks, they may be turned on the outside with a center midway between the other two centers.

52. Cams.—Though usually made on the milling machine, cams may sometimes be turned in a lathe. A templet is made with the same outline the cam is to have when finished, and fastened to the cam-blank. The screw in the cross-slide is removed so that the tool slide is free to move back and forth across the lathe saddle. A weight holds the tool against the work as it revolves with the templet. The tool is kept in the correct position by a stop that slides on the templet. This stop causes the tool slide to move in and out across the lathe carriage as the stop follows the outline of the templet. This process is not very rapid, but it will cut cams as accurate as the templet can be made. Other irregular shapes, such as machine handles, may be turned by making a templet and fastening it to the taper bar. The travel of the carriage will then cause the tool slide to move the tool in such a way as to turn the desired shape.

53. Turning Ovals.—In turning circular work in the lathe, the distance between the center of the work and the point of the tool remains constant. By referring to Fig. 33, it will be seen that if *a b c d* represents a circle with the center at *o*, and that if the tool were located at *a*, that as the work revolved and *b* approached *a*, so long as the distance from the center *o* remained constant the work would be turned to a circular form; but if by any means the center *o* could be made to approach the point *a* as the work revolved during one-quarter of a revolution, recede from it during the next quarter, advance during the third quarter, and recede during the fourth quarter, it would be possible to turn an oval. For instance, if, while the portion of the work from *a* to *b* were passing the tool at *a*, the center of the work *o* could be moved toward the circumference a distance equal to *b e*, the tool would cut along the curve *a e* of the ellipse *a e c f*. This is accomplished in a chuck for turning ovals by arranging a slide across the face plate and so adjusting the parts that it will move the work in or out across the face plate so as to produce the desired oval.

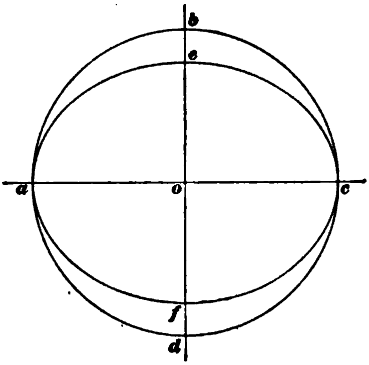


FIG. 33

54. An attachment for turning ovals is illustrated in Fig. 34, where it is shown attached to an ordinary lathe headstock. The work is secured to the plate *a*, or held in the chuck on a threaded spindle *b*. Back of the plate *a* there are two slides *c* and *e* at right angles to each other. The disk *d* has a long projection that reaches through and is attached to the regular lathe spindle of the headstock. The disk *d* acts as a driver for the plate *a*, the driving being done by means of the slide *c*. The slide *e* is secured by guides to the slide *c*, and is turned out on the side toward the headstock to receive a ring that is carried on the piece *f*. When the center of this ring is made to coincide with the center of the lathe spindle, the plate *a* and spindle *b* rotate as in an ordinary lathe; but if the piece *f* is moved across the lathe by means of the adjusting screws, one of which is shown at *h*, the ring attached to it will force the slide *e* to travel back and forth across the attachment as the work revolves, and this will cause the center of the plate *a*, and with it the work, to move back and forth, first away from and then toward the center of the lathe spindle proper. The result will be that an ellipse similar to that shown at *a e c f*, Fig. 33, will be turned.

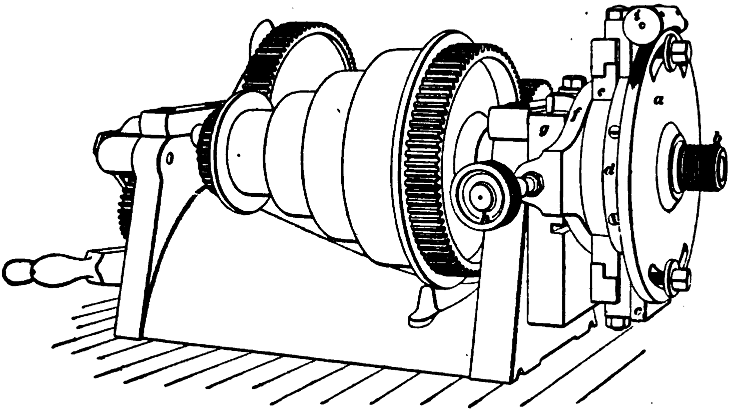


FIG. 34

55. The amount that the slide *f*, Fig. 34, is moved determines the amount of eccentricity of the ellipse; that is, the amount shown by the line *b e*, Fig. 33. The block *g*, Fig. 34, is bolted fast to the front of the headstock. In the form of chuck shown the plate *a* is provided with a screw *i*, and worm-teeth are cut for a short distance at the top of the plate. By means of these worm-teeth and the screw *i*, the plate *a* can be adjusted slightly in relation to the mechanism operating it. This device will be found very useful in resetting work in the chuck, as it serves to bring the work in line with the ellipse generated by the mechanism. This form of device is very handy for turning elliptical dies and punches, such as are used by jewelers, silversmiths, electrical-instrument manufacturers, and others.

FINISHING LATHE WORK

FILING AND SCRAPING

56. **Files for Lathe Work.**—Lathe work that is to be polished should be finished with a very smooth finishing cut, after which it may be made smooth by filing, or, if it is cast iron, by scraping. Just enough filing or scraping is done to remove the tool marks. The files used for this purpose are suitable sizes of smooth and dead-smooth double-cut files, single-cut mill files, and circular-cut files of the finer grades.

57. **Care of Files.**—The file selected for filing lathe work should be examined to see that the spaces between the teeth are clear and free from *pins*, which are small bodies of iron or steel that have been torn from the stock being filed and have become wedged tightly between the teeth. If the file is dirty, a file card or brush having fine wires instead of bristles, is used to remove the dirt by brushing vigorously crosswise in the direction of the teeth. If the file card fails to remove any pins that may be in the file, they must be picked out separately with the point of a scriber or a similar sharp tool. A piece of sheet brass or copper 3 or 4 inches long and from $\frac{1}{2}$ to $\frac{3}{4}$ inch wide may be used very effectively to remove dirt or pins by pushing it crosswise along the file teeth. The file teeth cut shallow grooves in the soft metal and the teeth so formed remove most of the dirt and pins. The file is then oiled evenly on both sides, usually with machine oil, and wiped fairly dry with waste. Some workmen omit the oil

and simply rub the whole of the cutting surfaces with chalk to prevent metal from sticking between the teeth.

58. Speed of Work for Filing.—The work to be filed in a lathe should be run at a speed about double that used for turning with carbon-steel tools, or somewhat more. However, if the file is brought against a piece revolving at an excessive speed the points of the teeth are soon worn away. When the work is small in diameter, it may be run at quite a high number of revolutions, so that in making one stroke of the file, the work will make a number of revolutions. This action is desirable when an attempt is being made to keep the work true. It is difficult to file the same amount from every point along the work, because one part of the work will be filed more than another, with the result that the longer the filing operation is continued, the more untrue the work becomes.

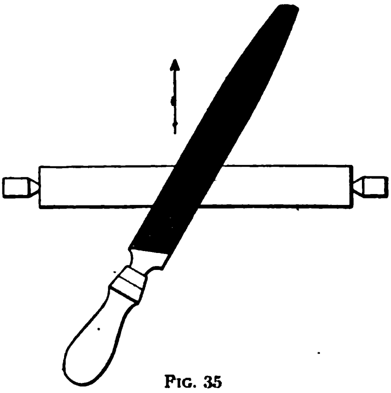


FIG. 35

59. Position of File. When filing, the point of the file should be held to the right so that it is at an angle to the work, as shown in Fig. 35. While held in this position, the file is moved squarely across the work, as shown by the arrow, although it appears as if it were moving toward the left. The file is held in this angular position so that its teeth will take a shearing cut on the cylindrical surface, which prevents chattering and the forming of pins in the file. The workman changes the angle of the file according to judgment, guided by his sense of feeling. If the file has a tendency to chatter, he changes the angle until it cuts smoothly. The circular-cut file, however, works best when held and moved squarely across the work; at the same time a slight horizontal circular movement is given to the elbow of the arm holding the file handle.

60. Even Filing.—When the work is large in diameter, it will be necessary to run it at a lower number of revolutions per minute. Suppose that the rate of file strokes is one a second, and the rate of revolutions of the work the same. Then, for one stroke of the file forwards, the work will make half a revolution, and it will be filed half around its circumference. While the file is being drawn back for the second stroke, the work begins its second revolution, and the file again cuts half of the circumference of the work. It will also be on the same side of the work. In this case, the file has cut twice on one side of the work, and has entirely skipped the opposite side. This will be continued as long as the rate of file strokes and revolutions of the work are the same. It may be seen from this that to keep the work nearly true, the file strokes should be slow enough to allow the work to make a number of revolutions for each stroke of the file. If the work is large, like a pulley, the file is held nearly stationary as the work revolves and just enough forward movement is given to avoid bringing all of the wear in one place on the file. If wrought iron or steel is being filed in the lathe and the workman finds the file filling up, he rubs his thumb and finger over the flat sides of the file to loosen the filings and raps the edge of the file lightly on the shank of a tool held in the tool post to jar the filings out. If they still stick tightly, he uses the file card.

61. Scraping Turned Cast-Iron Surfaces.—Flat and irregular turned cast-iron surfaces are prepared for polishing by scraping with a round-nosed hand tool. Such a tool is usually made from a worn-out flat file, and may be made right hand or left hand and of any convenient size. A flat surface is scraped in the lathe by clamping a tool in the tool post so that its shank will be close to and parallel with the surface. The work is speeded about the same as for filing and the hand tool is rested on the tool and brought lightly in contact with the work. The hand tool is then moved along the rest to remove a slight thickness of metal. This process is repeated until the surface is as smooth as required. Irregular surfaces are treated in a like manner. Very smooth work may be produced in this way, after a little practice.

POLISHING

62. Use of Emery Cloth.—After the tool marks have been removed by filing or scraping the piece is treated with a coarse emery cloth, well oiled, which will remove the file marks, after which a finer grade of emery is used until the coarser emery marks have been removed, and so on, using finer grades of emery until the desired polish is obtained. Emery cloth should be pressed quite hard against the work by a polishing stick, which is passed over the tool rest of the lathe and under the work, the emery cloth being held between the stick and the work. By pressing down on the outer end of the stick, the emery cloth can be brought with sufficient pressure against the work. The stick should be handled so that it will move back and forth on the work, so that the lines cut by the particles of emery will be constantly crossing and recrossing one another. Oil should be supplied to both the work and the emery, in a quantity sufficient to keep the surface moistened, but not in such excess that it will be thrown from the machine.

63. Speed for Polishing.—A higher speed is used for polishing than for filing. The higher the speed the better, provided the work and the machine are balanced so that the high speed does not shake the machine too much.

64. Care of Centers.—When a piece of work is being polished, enough heat may be generated to cause it to expand along its entire length. If, in the first place, the dead center has been made fairly tight, it will cut and stick in the end of the work, the oil having been burned out, and will be twisted off. This should be carefully guarded against by keeping the centers free and well oiled.

65. Finishing Polished Surface.—When the piece is nearly finished, the pressure of the emery is reduced and the movement along the length of the work is slower. For the finest grades of polish, fine crocus cloth is used and still finer polishes are produced by employing rottenstone. Not much machine work is carried to the perfection of polish that requires crocus cloth or rottenstone for finishing. A very high polish may be obtained by using a much worn piece of No. 0 or 00 emery cloth. Grain emery is often used on the speed lathe in the place of emery cloth; but this should be done only on a lathe used exclusively for polishing. Bare wood, or pieces of lead on the face of the wood, is used to hold the emery against the work. The particles of emery embed themselves in the soft wood or in the lead, and so are held from being thrown from the work. Oil is used as before. If the use of loose emery is necessary, the **V**'s and bearings of the engine lathe should be well covered, as they will be injured by the emery.

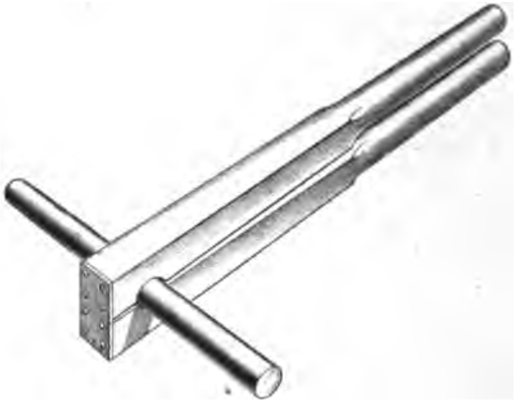


FIG. 36

66. Polishing Clamp.—For plain cylindrical work, a very convenient and effective way of holding the emery against the work is brought about by fastening two pieces of wood together at the end with a leather hinge. The two inside faces of the pieces are cut out at a short distance from the hinged end, so that they will fit over the shaft, as shown in Fig. 36. By pressing the outer ends together, considerable pressure is brought against the shaft. Either emery cloth or grain emery may be used with this device.

ERRORS IN LATHE WORK

CAUSES OF ERROR

67. The chances for error in machine work are numerous. No sooner is one difficulty overcome than another appears. The workman must never take anything for granted regarding the accuracy of a machine or the work it is producing until he has made sure that all is right by a personal investigation. Even then he must be on the watch, or unexpected errors will creep in. These small errors that occur in lathe work become more numerous and troublesome as the degree of accuracy is increased. Things that would not be noticeable in an ordinary line of work become very important in accurate work. Error in cylindrical turning may be caused by spring of the tool, spring of the work, or inaccurate adjustment of the machine.

SPRING OF LATHE TOOLS

68. Causes.—The amount that the tool will spring depends on the position it holds in relation to the work; on the rigidity of the tool; on the closeness of fit between the tool block and the slide; on the stiffness of the shank of the tool; and on the shape of the tool.

69. Position.—When the point of a tool is set above the center of the work, as it bends in its shank the point tends to follow in an arc of a circle drawn about the bending point. If this arc cuts into the work, the tool, following in that path, will spring deeper into the work. If the tool is so located that when it bends or springs the arc moves away from the work, then the tool will spring away from the work. It would therefore seem that the best place to set the point of the tool would be level with the center, so that, if the tool springs, it will not spring into the work. A tool properly shaped for this position would have very little front rake, and its keenness would be given entirely by increasing the angle of top rake. Such a tool is absolutely required for taper turning; but for ordinary turning other conditions arise, making it objectionable. When this tool is used, the total force acting on it is in a direction tangent to the diameter of the work at the point of the tool.

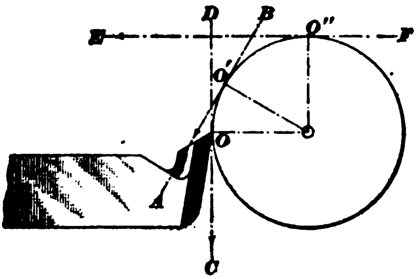


FIG. 37

70. When a tool without front rake is used, the force will be directly down, or perpendicular to the top of the lathe bed, in the direction of the arrow DC, Fig. 37. As increased front rake is given to the tool and it is set higher on the work, the line of force changes its direction, so that if the front rake is 30°, the force acting against the point of the tool at O' will be in the direction of the arrow BA. When the force on the tool is in the direction of the arrow BA, it tends to force the tool block back from the work; this causes some pressure on the cross-feed screw. If the tool had still more front rake and were set higher, the pressure on the cross-feed screw would increase; and if the tool could be set as high as the point O'', the force of the cut would be in the direction of the line FE, which would be entirely against the cross-feed screw. This pressure against the cross-feed screw is very desirable. It holds the tool block back and takes up the lost motion that may be in the screw, so that, when an adjustment is being made, any partial turn of the screw at once acts in moving the tool block. It also allows the tool to be held in such a position that there is little danger that the pressure of the shaving on the top face of the tool will pull the tool and tool block forwards, thus taking up the lost motion in the cross-feed screw.

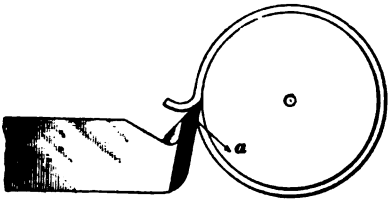


FIG. 38

71. From Fig. 38 will be seen that when a tool is set at the center and ground with much top rake, the pressure of the shaving on the top face is in the direction of the arrow *a*. This direction is so nearly parallel to the line of the cross-slide that, if the slide is loose or the screw has lost motion, the tool will tend to slide into the cut. If the tool is set higher, this force on the top face is in the direction shown in Fig. 39, and there is little tendency to drag the tool into the cut. Practice, therefore, has settled on tools with a fair amount of front rake, which allows them to be set above the center of the work, and gives the desired pressure against the cross-feed screw.

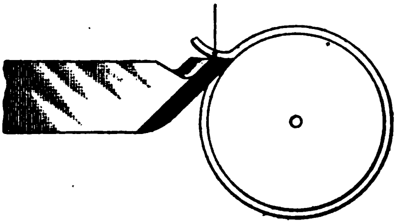


FIG. 39

72. Variations in Depth of Cut.—If, in turning a piece, an attempt is made to finish the work very close to size with the first cut, leaving a very light cut for the last, the following results may ensue: The tool is started and the cut taken for a short distance, and by a series of fine cuts the work is brought to the desired diameter shown at *a*, Fig. 40. The feed is thrown in and soon the tool starts in the heavy cut. As soon as the heavy pressure comes on the tool, it springs and takes a still heavier cut. The piece is thus turned smaller in diameter, as shown by the dotted lines, and in many cases may be made below the desired size. This is one reason why at least $\frac{1}{64}$ inch should be left for finishing.

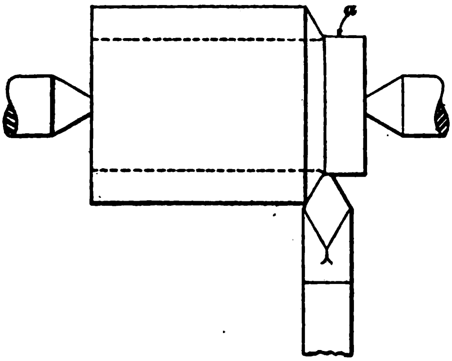


FIG. 40

73. In another case, a casting or a forging has a large lump on one side, as in Fig. 41, and this must be turned off. Because of the form of the work, the shaving will be of different thicknesses, and consequently there will be different pressures on the tool, which will thus be caused to spring to various depths in the work, with the result that the piece will be neither round nor true, and that a second finishing cut will be necessary.

74. Reducing Error Due to Spring of Tool.—The possibilities of error due to the springing of the tool are guarded against by using tools with heavy shanks, clamping the tool very close to the cutting edge, and in adjusting the tool block so that there is no lost motion in the slide. With these precautions, work may be performed, so far as the tool is concerned, with sufficient accuracy for all ordinary machine construction. In discussing the spring of the tool, it has been assumed that the work was very rigid, so that all the spring occurred in the tool. The tool, however, must not be held responsible for all error, as much is caused by the spring of the work.

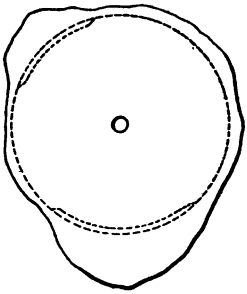


FIG. 41

SPRING OF THE WORK

75. Effect of Weight of Work on Spring.—Any action that may cause the work to bend or deflect so that its axis is not a straight line will cause the work to be untrue. If the piece is short, and its diameter great, the spring is less than when the work is long and slender. In long pieces, the weight of the piece between the center is sufficient to demand attention.

76. Effect of Force of Cut on Spring.—The force required to turn a shaving acts against the tool, tending to spring it down, and reacts in the opposite direction, tending to bend or spring the work up. When the tool is starting at the end of the work, there is less deflection than when it has reached the center. If a bar is supported at the two ends and a load applied at the center, it will deflect more than if the load is applied very near the ends. Because of this great deflection at the center of the work, the tool cannot cut so deeply; consequently, the work, when turned, will be larger at the center than at the ends. This error must be corrected by taking very light finishing cuts, or, in the case of long slender pieces, the work must be supported by the use of steady rests.

SPRING DUE TO METHOD OF DRIVING

77. Action of Bent-Tail Dog in Springing Work. Probably as much spring in cylindrical work is produced by imperfect methods of driving or rotating the work in the lathe as in any other way. The ordinary bent-tail dog so commonly used produces a variety of strains in the work, some of which are constant and some variable. All, however, tend to distort the work. These forces may be considered separately. First, there is a leverage from the point of the live center. The amount of this leverage depends on the length of the live center. This is shown in Fig. 42, which represents a side view of a piece of work between the centers. The tail of the dog is at the back of the machine. Suppose the tailstock end *b* of the piece to be clamped rigidly so that it cannot turn. If power is applied to the lathe the work will tend to turn toward the operator in the direction of the

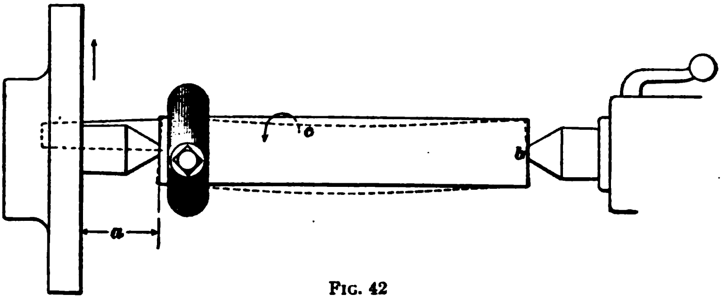


FIG. 42

arrow *c*; but as it cannot, the piece is put under such a strain that it springs. The leverage is represented by the distance *a* that the lathe center projects beyond the face plate. The force of the face plate, which tends to lift the tail of the lathe dog, acts from the point of the center as a fulcrum and tends to bend the work down, as shown by the dotted lines. If the lathe center were longer, there would be a greater force tending to spring the work because of the increased length of leverage *a*.

78. When the tool begins to cut at the end *b*, Fig. 42, the resistance of the cut at this point acts the same as if the work were clamped at this end as just described. The effect is the same, though not so great, as clamping the end; for with a tool the strain can never be greater than that required to cut the shaving. As the tool feeds along, this resisting point approaches the point of the live center or the fulcrum from which the work bends. The result is that the amount of spring of the work will change. There is thus a changing force tending to spring the work; this force depends on the position of the tool along the work.

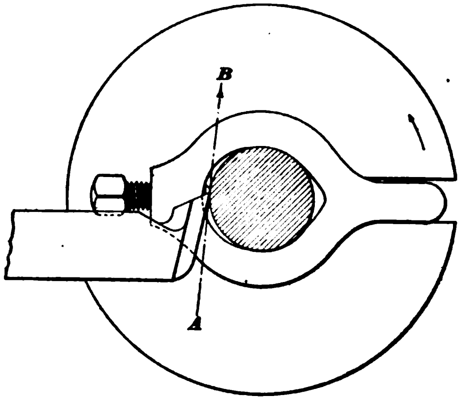


Fig. 43

79. Suppose that, in another case, the tool is cutting in a position midway along the length of the work. A section through the work is taken at this point, as shown in Fig. 43. This shows the tool at the front with the tail of the dog diametrically opposite. As the work revolves toward the operator in the direction of the arrow, the force required to turn the shaving is made with an upward pressure of the tool, which tends to spring the work up in the direction of the arrow *A B*. The force required to revolve the work tends to spring the work down, as the dog is at the back of the lathe, and the forces act as shown in Fig. 42. In this case, there are two forces tending to spring the work in opposite directions and to balance each other; namely, the force of the cut and the pressure on the lathe dog.

80. When the work makes half a revolution so that the tail of the dog is at the front, as in Fig. 44, the force of the cut will act in an upward direction *A B* as before; but the pressure on the tail of the dog will be now in the same direction. Hence, there will be two forces, both tending to spring the work up. In the first case, it is the difference of the forces that tends to spring the work. In the second case, the sum of the forces acts to spring the work up. Here, again, because of the varying forces, various degrees of deflection occur.

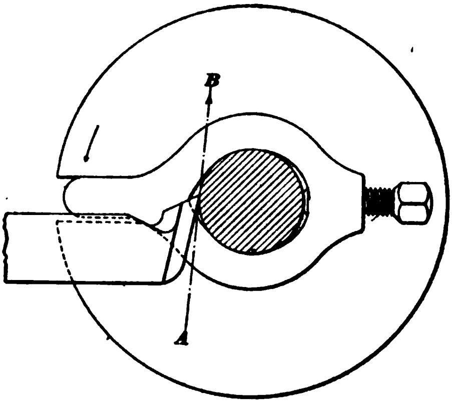


FIG. 44

When a straight-tailed dog and a driving pin, as shown in Fig. 45, are used, the conditions are reversed, the effect of the leverage of the bent-tailed dog being entirely eliminated, so that when the dog is at the back, both forces tend to spring the work up, and when the dog is at the front, the two forces are opposite and tend to balance each other.

CORRECT METHOD OF DRIVING

81. Straight-Tailed Dogs.—Fortunately, the complicated strains arising from the ordinary methods of driving the work may be eliminated by changing the driving devices.

The distortion shown in Fig. 42 may be remedied by using a straight-tailed dog and a driving pin in the face plate, as shown in Fig. 45. A joint is thus obtained between the pin and the dog, which breaks the leverage *a*, Fig. 42, and so eliminates the bending strain.

82. The variable forces represented in Figs. 43 and 44 may be balanced by using a two-tailed dog and two driving pins in the face plate, as shown by Fig. 46. When the work is thus driven, the two forces at the ends of the dog balance each other, and the only force remaining that tends to spring the work is the upward force of the tool. If the pressures at the ends of the dog do not balance, the same trouble that is found with the single-tailed dog will appear.

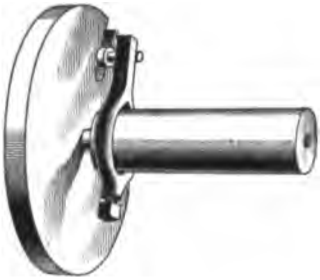


FIG. 45

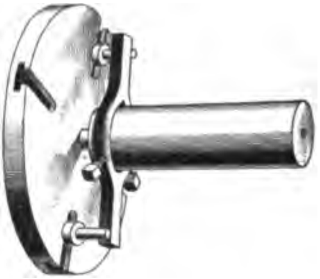


FIG. 46

83. Great care is necessary in adjusting the driving pins in the face plate so that the same pressure will be brought against each pin. In some instances this may be accomplished by moving one of the pins in the slot of the face plate in or out from the center. As the tail of the dog and the slots in the face plate are not parallel, moving the pin toward the center will bring it against the dog, and moving it from the center will move it away from the dog. The pressure on the pins may be tested with pieces of paper put between the dog and the pins. The work is turned backwards by hand on the centers, to hold the dog against the pins, and the paper is tested by pulling. Any inequality in pressure may thus be detected.

84. Equalizing Dogs.—Instead of adjusting the pins each time, an equalizing dog, Fig. 47, may be used. In this case, the dog is adjusted to the pins by tightening or loosening the clamp screws *a* and *b*, as may be necessary. Although it is very desirable to drive the work by the methods described, the difficulty in adjusting the dogs and the uncertainty that they will remain as adjusted do not warrant their general use. When some device can be used that will automatically balance or equalize the pressure on the pins, this method becomes more practicable. Many forms of equalizing dogs have been devised. They serve better for small than for large work.

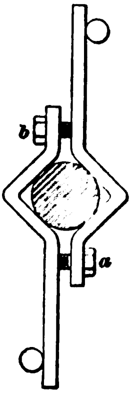


FIG. 47

85. A very convenient and successful method of equalizing the pressure on the pins when the two-tailed dog is used, is by means of the equalizer or driver shown in Fig. 48. This consists of a plate carrying the driving pins *p*. The plate is fastened loosely to the front face of the face plate by means of bolts or studs screwed solidly into the face plate but fitting loosely in the long slots *s* in the driver. The studs keep the driver from slipping around on the face plate, but give it freedom to move a distance along the slots equal to their length. Suppose, in use, the greater pressure of the dog first comes against the top pin. The pressure would force the entire driver back, which would slide the lower pin up to the dog. As soon as the pressures balanced each other, the plate would stop sliding and continue to keep up the equilibrium.

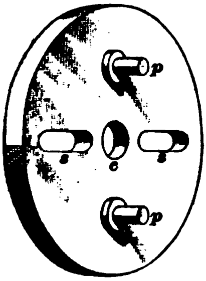


FIG. 48

ERRORS IN MACHINE

86. Poor Adjustment.—Imperfect work may often be traced to the poor adjustment of the machine or to the fact that the machine is much worn. When the lathe is in this last condition, it will be noticed that the spindle is slightly out of line with the bed and that it will neither bore holes straight nor face surfaces true. A great deal of wear comes on the lathe bed at a part quite near the headstock, because the greater part of the work turned on the lathe is short, and the carriage moves over this part more than any other. If the gibs that hold the carriage to the bed are so adjusted that the carriage is in good adjustment at this worn place, it will be found that when longer work is to be turned, the carriage will not slide easily along the unworn part of the bed.

87. **Accuracy of New Lathes.**—In the manufacture of lathes, all parts are carefully tested to see whether the center line of the spindles is exactly parallel with the bed, the carriage square across the bed, and all parts correct. All these tests require that the lathe shall produce work within a limit of from .00025 to .001 inch, depending on the kind of work. The accuracy of the machine is not so important as the skill of the operator, for a skilful and careful workman will overcome the inaccuracies of the machine; but the careless workman will have trouble even with the best machine.

88. **Necessity for True Centers.**—The live center should always run true. The dead center should be truly conical and smooth. If a live center were out of true, or eccentric, so that its point wabbled slightly and a piece of work were turned on it, the work might be round and straight, but the turned part would not be true with the center hole. A piece may be turned to various diameters and shapes on untrue centers and the different cuts may all run true with each other, provided they were all taken at one setting. If, however, the dog had been loosened and a half turn given to the work, the dog being again clamped, the piece just turned will run out of true an amount double the error of the live center. When, therefore, a piece is partly finished on one machine and then taken to another for final finishing, it is necessary that the centers be true on each machine. If the second workman finds that the outside of the work does not run true, he should make sure that the centers are true; if

such is the case, the center holes should be scraped until the turned part runs true on the dead centers.

89. Scraping Center Holes.—If work is found to be out of true with the center holes, they may be brought true with the work by scraping. Center holes are scraped after first cleaning both lathe centers and work centers. The work is then placed on centers without putting a dog on it. A parting tool is clamped in the tool post, as for cutting, but preferably with a piece of white paper or card laid below the tool. The tool is then run up to the work near one end and the work is revolved backwards past the tool point by one hand while the tool is fed up to the work with the other. By looking through between the work and the tool any eccentricity is easily seen over the white paper. The high side is chalked, the piece is taken from the lathe and gripped in the vise with the high side down, so that the side of the hole to be scraped will be nearly horizontal, as shown in Fig. 49. The three-cornered scraper is placed in the hole with two of its edges in contact with the hole and pressure is brought on it with both hands, so that one edge is in more intimate contact with the surface of the hole than the other. This action determines which is the cutting edge. The scraper is rotated slightly and may be moved to cut either toward or away from the operator. The scraping is started at the middle of the untrue part, where the most metal is to be removed, and is reduced in both directions to keep the hole round. The work is then returned to the lathe, tested as before, and the operation of scraping continued until the outside surface runs true at both ends. Care should be taken that the scraping is done so that the completed surface of the hole will show

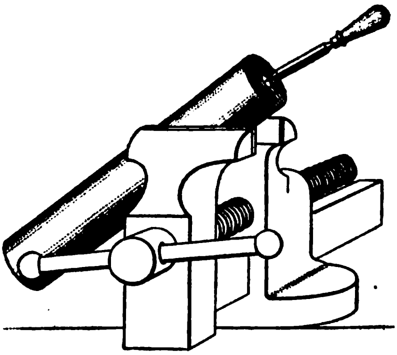
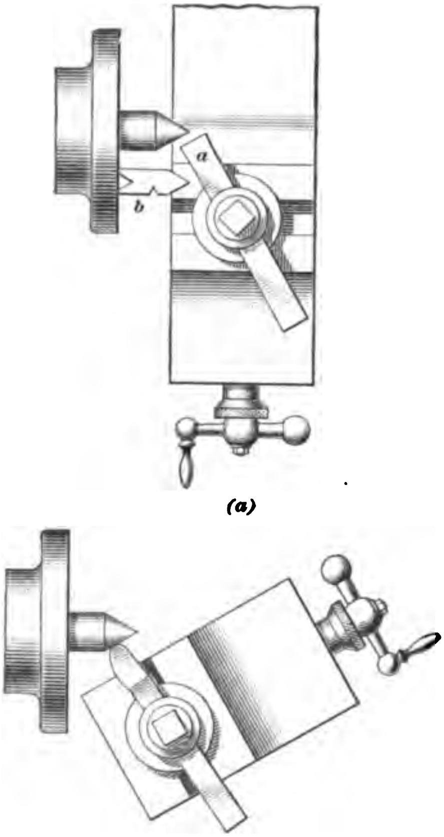


FIG. 49

a good bearing on the lathe centers. A dog should never be used to rotate the work while testing for scraping, because it might spring the work; also, it would not be in balance and it would double any error that might be in the live center.



(a)

(b)

Fig. 50

90. Hardness of Centers.—The dead center is always hardened and tempered. The live center may or may not be as hard. Sometimes a softer live center is used, as a very fine cut can be taken from it as it revolves with the spindle. This makes it practically true, and little time is expended in truing it; but because of its greater softness, it is easily made untrue by bending or bruising. If a center, after being trued, is hardened and tempered and then put back in its place, it will no longer run true, owing to the warping or springing in hardening and tempering. To use hardened live centers successfully, they must be made true by grinding as they revolve with the spindle. The live center is hardened and the temper drawn to such a point that it can just be turned, if there are no facilities for grinding the center in position in the spindle. Grinding, however, is preferable to turning.

91. Turning of Live Center.—A lathe having no compound rest may be used for turning the live center true by clamping in the tool post a broad-nosed tool *a*, Fig. 50 (*a*) having its edge ground perfectly straight. The cutting edge is set to an angle of 30° with the center axis by adjusting it to a center gauge held with its open end against the face plate, as shown at *b*. The lathe is speeded up and three or four light forming cuts are taken from the center, starting at the point. Care should be observed, when the last cut at the large diameter is taken, that the tool does not catch as the whole length of cutting edge begins to cut, for this is liable to spoil both center and tool. The finishing cut should very lightly scrape the center and leave it true. It is then filed lightly with a smooth or dead-smooth file and polished with emery cloth. If the lathe has a compound rest, the rest is set to the required angle and an ordinary turning tool clamped in the tool post as shown in (*b*). A light cut is taken over the center, which is afterwards lightly filed and polished.

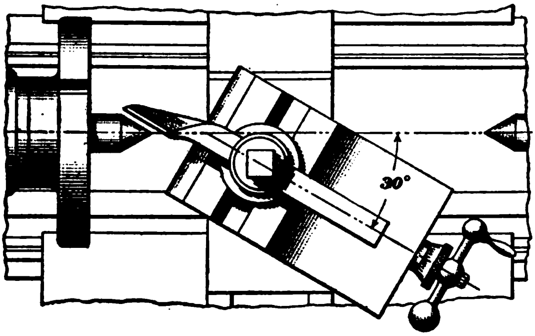


FIG. 51

92. Lathe centers may be trued by swinging the compound rest to an angle of 30° with the line of centers and using a left-hand side tool, as shown in Fig. 51. The side tool is set so that only a small part of the point cuts, and is fed along the taper of the center by the compound rest, while the lathe is running backwards. If there is no compound rest, the tool may be set in the tool post and adjusted to an angle of 30° with the line of centers, as shown in Fig. 52.

Lathe centers are sometimes trued by hand, particularly in a speed lathe, by setting a holder or rest parallel with the tapered part of the center, as shown in Fig. 53, and doing the cutting with either a diamond or a flat hand tool. The metal is removed by light scraping cuts until the center fits the gauge, after which it is lightly filed and polished as in the other cases.

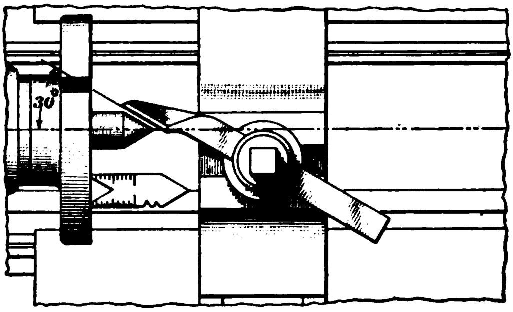


FIG. 52

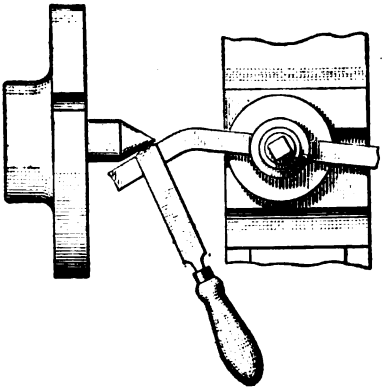


FIG. 53

93. Grinding Lathe Centers.—A properly constructed grinding machine should be used to grind lathe centers. There are many forms of center grinders manufactured that are sufficiently convenient to warrant their use in many shops. Fig. 54 shows a very convenient form and its application to the lathe. In setting this grinder in the lathe, the shank *a* is passed loosely through the tool post of the lathe and the lathe centers come into the reamed center holes *b* in the grinder. These center holes have been so located that they hold the axis of the grinding wheel *c* at an angle of 30° with the axis of the lathe. After adjusting the rest to such a height that the shank *a* bears fairly on its bottom, it is clamped rigidly in the tool post. The dead center may be removed, which allows the centered part *b* to move clear of the live center, and the machine adjusted so that the emery wheel comes against the lathe center. A rubber wheel *d* is pressed against the cone pulley by the handle *f*. The lathe is run at its fastest speed backwards, while the emery wheel is moved along the face of the center by moving the shaft operated by the knob *e*.

If electricity is used in the shop, a portable center grinder is clamped in the tool post and connected by wire with a light socket. The wheel is then fed back and forth over the center until it is true. There are also stationary center-grinding machines in which dead centers are placed and ground rapidly and accurately.

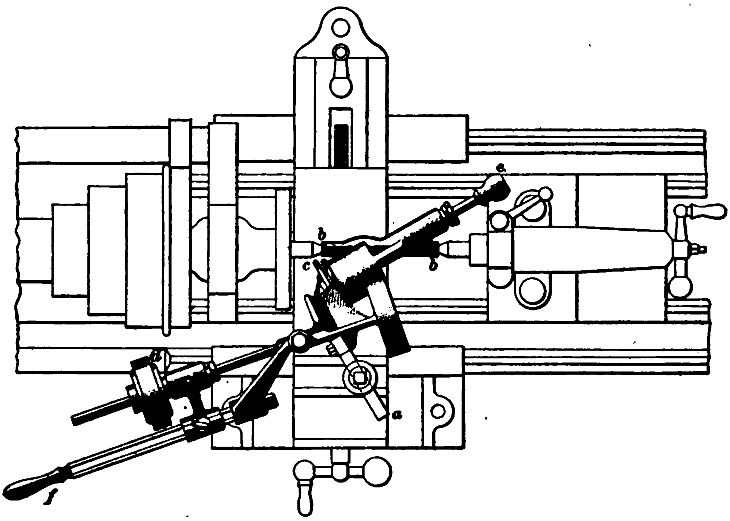


FIG. 54

94. When both centers are to be trued, the dead center should be trued first. It is put in the place of the live center, and there ground smooth and true. It is well to polish the dead center with emery cloth and oil. The live center may next be ground and left in place after grinding, so that it will run true. Before grinding or truing a center, great care should be taken that the center hole in the spindle is very clean before the center is put in place. If any dirt or specks of shavings are between the center and the hole, they will hold the center away at that point and make an incorrect fit. The center might be trued while in this position and it would run true until the dirt was removed, whereupon it would at once be untrue.

95. Removal of Live Center.—Unless absolutely unavoidable, live centers should never be removed from the spindle of the lathe. When chucks are used on lathes and rods are passed through the spindle, it becomes necessary to remove the centers. If only for plain chuck work, the center hole should be plugged with waste, as it is very difficult to remove the dirt that accumulates from the work when the hole is left open.

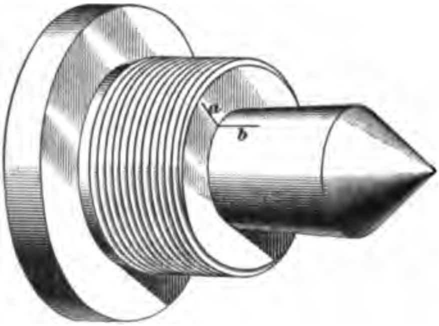


FIG. 55

It is often the case that the center hole in the spindle is not absolutely true and that if the center is true in one position in the hole, it will run untrue when given a part of a revolution to another position. In all cases it is best to mark a line along the length of the lathe center *b*, Fig. 55, and draw a radial line *a* on the nose of the lathe spindle. The center should always be replaced in the spindle by making the marks *a* and *b* coincide, as shown. After lathe centers are once made true, they should be kept in good condition. Care should be taken to keep the dead center well oiled. When the live center appears to be true, but has not been recently ground, its truth may be tested. A very common method of testing the center is to set a broad-nosed tool to the center angle and run it nearly up to the center. A piece of white paper or a steel rule is held under the tool and by looking through between them any untruth of the center can be seen.

96. Lining Lathe Centers.—To turn work square and parallel, it is necessary that the lathe centers be in line with each other and with the line of tool motion. If the centers are much out of line, as they would be after turning a taper, they may be roughly set by placing the dead center very close to the point of the live center and adjusting until the points appear to be opposite, or the dead center may be set by the use of the scale or zero mark on the tailstock. To adjust the dead center accurately, a test bar about 1 foot long may be used. It is carefully centered with its ends finished to the same diameter, and the middle portion slightly reduced. This bar is held between the lathe centers and the tool is adjusted to touch the bar at the live-center end. After the tool is thus adjusted, the carriage is moved to the dead-center end and the tailstock is adjusted so that the tool just touches the bar at this end. The test should be repeated until the centers are alike at both ends. After the centers are lined, the work being turned should be carefully calipered as the cut proceeds, to be sure that the lining was correctly done.

97. Wear of Tool.—Sometimes when the centers are correctly lined, the work may be slightly tapered, growing larger at the headstock end, owing to the wearing away of the point of the tool. A long, springy shaft will taper larger as the tool feeds toward the head during a heavy cut. This taper will increase until the middle is reached, and decrease the remainder of the distance. Taper resulting from spring usually corrects itself during the finishing cut.

LATHE WORK

(PART 5)

LATHE OPERATIONS

SCREW THREADS

GENERAL PRINCIPLES

1. A **machine-screw thread** is the ridge left on a cylindrical piece by cutting a helical groove around the piece with a tool that at each turn of the work advances regularly through a distance greater than the width of the tool. The helical path of a screw thread may be represented by winding a string in a spiral from one end of a pencil to the other and keeping the turns evenly separated.

2. A plain screw thread on the end of a bolt is shown in Fig. 1. The **diameter** of a thread is the diameter measured over the points, or the diameter d of the bolt, before the thread was cut. The outer edge a, where the sides of the thread meet, is the **point** of the thread; and the inner point b, where the adjacent sides meet, is the **root** of the thread. The **root diameter** is the distance through the core of the screw from root to root, as d_1. The **height** of the thread is the vertical distance h from the root to the point. The **pitch** of the thread is the distance p from the point of one thread to the point of the next, measured parallel to the axis of the bolt.

3. When cut on the outside of a piece of work, a screw thread is an *external thread*, or *male thread*, and one cut on

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the inside is an *internal thread*, or *female thread*. A bolt is a familiar example of external thread, and a nut is an example of internal thread. If the piece on which a thread is cut, when it is being screwed into a nut, must be turned in the direction of the hands of a watch, the thread on it, and in the nut also, is a *right-hand thread;* but if the piece must be turned in the other direction, the thread is a *left-hand thread*. Threads are usually of the right-hand type.

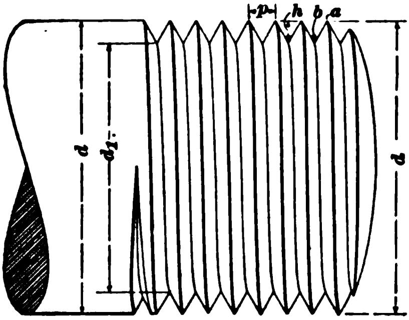


FIG. 1

4. A *single thread* has one spiral groove cut around the bolt, leaving one spiral ridge, or thread, as in Fig. 1. A *double thread* has two spiral grooves cut around the bolt side by side, thus giving two spiral ridges, or threads. Fig. 2 shows a double thread. One thread is cut farther along the bolt than the other, to show how the first thread is cut. A *triple thread* has three spiral grooves, and consequently three spiral ridges or threads. If two strings are wound at the same time about a pencil, keeping them side by side, the strings will represent a double thread. If three or four strings are used, a triple or a quadruple thread will be illustrated. The *lead* of a thread is the distance it advances in making one complete turn, or the distance from a point on one thread to a corresponding point on the *same* thread after

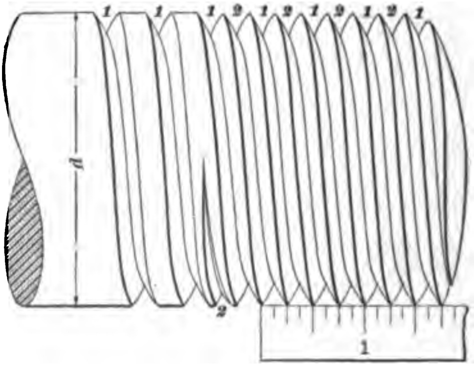


FIG. 2

it has made one turn. The lead of a double thread is twice the pitch; of a triple thread, three times the pitch; and of a quadruple thread, four times the pitch. Double, triple, quadruple, etc. threads are called *multiple threads*.

5. **Measuring Screw Threads.**—It is customary to designate a screw thread by the number of turns it makes in advancing 1 inch along the axis. The number of turns may be found in different ways, as shown in Fig. 3. For example, at *a* is shown a scale set on the screw so that its end is in line with one thread point. Another thread point is opposite the first inch mark. Counting from the end up to and including the first inch mark, there are six thread points, as numbered; but the sixth point is really the first point in the next inch, so it is dropped. There are 5 points per inch, therefore, and so the screw is said to have five threads per inch.

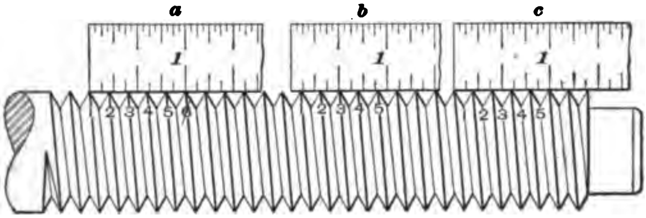


FIG. 3

6. Another method of finding the number of threads per inch is shown at *b*, Fig. 3. The end of the scale is set in line with the root of a thread space, and the number of points between the end of the scale and the first inch mark is counted. In this case, there are five points; consequently, the screw has five threads per inch. Still another method is to place the scale as at *c*, with one end in line with a thread point, and to count the number of spaces between the end and the first inch mark. In this case there are five spaces, showing that the screw has five threads per inch.

7. The three methods that have just been described give correct results *only* when there is a whole number of threads

per inch; that is, the end of the scale and the first inch mark must both coincide with thread points. If the end of the scale is in line with a thread point and the first inch mark comes opposite a space, the screw has a fractional number of threads. In such a case the counting must be continued until a point is reached where a thread point coincides with a full-inch mark; then, the total number of points counted, less one, divided by the number of inches, will give the number of threads per inch. For example, in measuring a certain screw the end of the scale is even with a thread point, and 24 points are counted before a thread point again comes opposite a full-inch mark, which is the 2-inch mark. Dropping the last point counted, there are twenty-three points in 2 inches, or $23 \div 2 = 11\frac{1}{2}$ points per inch; therefore, the screw has eleven and one-half threads per inch.

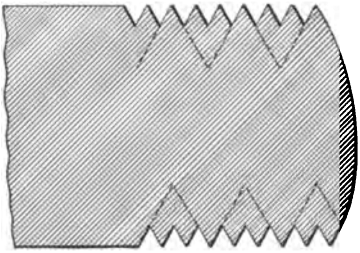


Fig. 4

8. In measuring a multiple-threaded screw, the lead is usually desired. In the case of a double-threaded screw, like that in Fig. 2, only every other point would be counted, giving two points to the inch; then, the lead would be $\frac{1}{2}$ inch. The actual number of threads per inch is four, and the pitch is $\frac{1}{4}$. Multiple threads are used when a large lead is desired on a screw of small diameter. By cutting a number of threads in place of one large thread, it is possible to keep the coarse lead without cutting very deeply into the piece. Fig. 4 shows a section of a screw with triple threads. The dotted lines show the depth to which it would be necessary to cut a single thread of the same lead.

9. **Expressing Pitch.**—As the pitch of a thread is the distance from one thread to the next, it should properly be expressed in fractions of an inch. Thus, a screw of $\frac{3}{8}$-inch pitch has threads that lie $\frac{3}{8}$ inch apart from point to point. It is customary in many places, however, to refer to the pitch by the number of threads per inch; for example, a 6-pitch

screw is one that has six threads per inch, and a 10-pitch screw is one that has ten threads per inch. The pitch is always equal to 1 divided by the number of threads per inch; thus, if a screw has twelve threads per inch, the pitch is $\frac{1}{12}$ inch.

10. Common Forms of Threads.—The forms of screw threads used in the United States are the sharp, or **V**, thread, the United States standard thread, also known as the Sellers, or Franklin Institute, thread, the square thread, the Acme thread, the worm thread, the metric thread, the ratchet thread, the British standard thread, and some others used for special purposes. The two forms most commonly used in the United States are the **V** thread and the United States standard thread. They are used on commercial bolts and screws and for fastening devices in machine construction.

SHARP, OR V, THREAD

11. Shape.—A section through a part of a bolt showing the exact shape of a **V** thread, is given in Fig. 5. The sides of the thread are straight and make an angle of 60° with each other, and 60° with the center line of the screw. These side faces meet and form a sharp point *a* and a sharp corner *b* at the root; hence its name, sharp, or **V**, thread. The pitch is here denoted by *p*, the height of the thread by *h*, the diameter of the bolt by *d*, and the diameter at the root of the thread, or the diameter of the tap drill, by d_1.

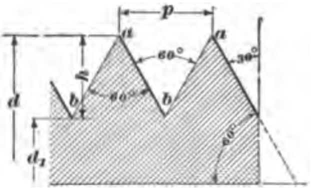


FIG. 5

12. Tool for Cutting V Threads.—The sharp or **V** thread has been almost universally adopted for making case-hardened setscrews. The number of threads per inch is shown in Table I. The **V** thread is widely used for very small screws having fine pitches, and also in a modified form for pipe threads. The threading tool for **V** threads is shown in Fig. 6. It is ground flat on the top face, and the front faces and cutting edges *N S* and *G K* are ground to form an angle of 60°. This angle is tested by the *center gauge* shown in Fig. 7, which has 60° notches cut in it. The point of the tool is set in the notch

TABLE I

SHARP, OR V, THREAD

Diameter of Bolt Inch	Number of Threads per Inch	Diameter at Root of Thread Inch	Diameter of Bolt Inches	Number of Threads per Inch	Diameter at Root of Thread Inches
$\frac{1}{4}$	20	.1634	$1\frac{1}{8}$	7	.8776
$\frac{5}{16}$	18	.2163	$1\frac{1}{4}$	7	1.0026
$\frac{3}{8}$	16	.2668	$1\frac{3}{8}$	6	1.0863
$\frac{7}{16}$	14	.3138	$1\frac{1}{2}$	6	1.2113
$\frac{1}{2}$	12	.3557	$1\frac{5}{8}$	5	1.2786
$\frac{5}{8}$	11	.4676	$1\frac{3}{4}$	5	1.4036
$\frac{3}{4}$	10	.5768	$1\frac{7}{8}$	$4\frac{1}{2}$	1.4901
$\frac{7}{8}$	9	.6826	2	$4\frac{1}{2}$	1.6151
1	8	.7835			

of the gauge, which should lie flat in line with the top surface of the tool. The angle of front rake, or clearance, is 15°, as indicated by the angle between the lines *C D* and *E F*, Fig. 6.

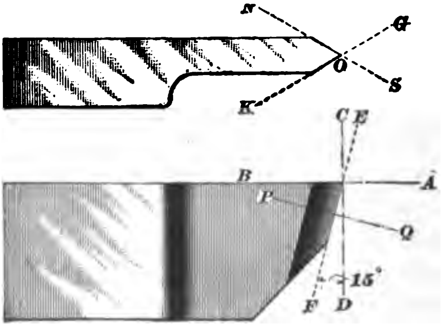


FIG. 6

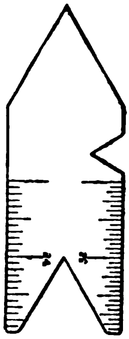


FIG. 7

A tool for heavy work is shown in Fig. 8; this has the disadvantage that it grows thicker each time it is ground, thus making it more difficult to cut threads close to a shoulder. Very often the tool is made offset, as shown in Fig. 9.

13. Setting Threading Tool.—Threading tools should be clamped in the tool post at such an angle to the work that the cutting edges *N S* and *G K* of the tool, Fig. 10, will make equal angles with the work. This is accomplished by using a center gauge, as shown. The back of the gauge lies flat against the work, and the point of the tool is so moved that it just fits the notch in the front of the gauge. As the point of the tool is ground to an angle of 60° and the sides of the threads to be cut make an angle of 60°, the angle between one of the faces of the tool and the work will be an angle of 60°. It will therefore be found more convenient on some kinds of work to hold the gauge as shown in Fig. 11, with one angular edge against the work, and to set the tool to the other angular edge. When one edge of the tool is properly set, the other edge will be at the correct angle, provided the tool is correctly ground.

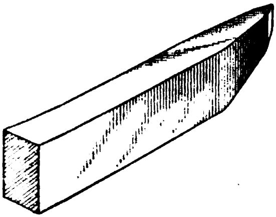


FIG. 8

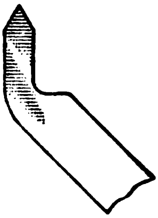


FIG. 9

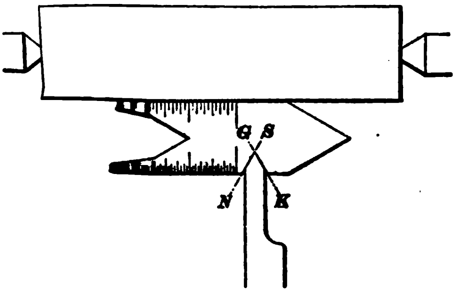


FIG. 10

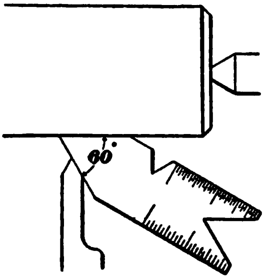


FIG. 11

14. Grinding Threading Tool.—The threading tool may be ground by the same method used in grinding ordinary lathe tools, the gauge being used to test the angle of the point. Whenever possible, it is better to grind the tool in a machine especially designed for the purpose. With these machines, it is possible to grind more accurate angles and truer faces than by hand.

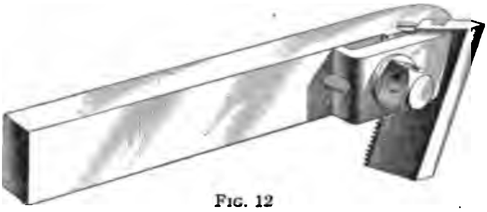


Fig. 12

15. Inserted-Blade Threading Tools.—Various forms of tool holders have been designed for threading tools. Fig. 12 shows one of these forms for **V** threads. The tool is accurately made and ground so that the front faces form such an angle with each other when the top face is ground flat that the angle of the cutting edges will be 60°. The inserted blades are sharpened by grinding the top faces. Tool holders are made for cutting square threads, blades of various thicknesses being used to cut the various pitches of threads. When coarse pitches on small diameters are to be cut, these tools cannot be used, because of the excessive side rake required on tools employed for this purpose.

UNITED STATES STANDARD THREAD

16. Shape.—The shape of the United States standard thread is shown by the full lines in Fig. 13. In order to compare it with the sharp **V** thread, a **V** thread of equal pitch is drawn in dotted lines. The sides of the United States standard thread make an angle of 60° with each other and with the center line of the bolt, just as in the **V** thread; but the point and root of the United States standard thread are flat. The amount of this flatness may easily be determined. Suppose that the height of a **V** thread of the same pitch is divided into eight equal parts, as shown, and one-eighth of the point is cut off. The point would then have a flat, as

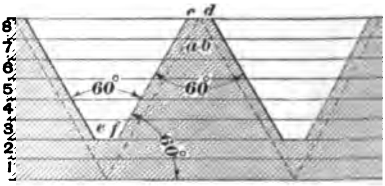
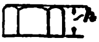
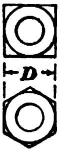
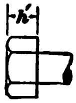


Fig. 13

TABLE II

UNITED STATES STANDARD BOLTS AND NUTS

Bolts			Nuts			Heads
Diameter Inches	Number of Threads per Inch	Diameter at Root of Thread Inches	Thickness of Nut  Rough Inches	 Rough Inches	Diameter of Tap Drill Inches	D the Same as for Nuts  Rough Inches
1/4	20	.185	1/4	1/2	3/16	1/4
5/16	18	.240	5/16	19/32	1/4	19/64
3/8	16	.294	3/8	11/16	5/16	11/32
7/16	14	.345	7/16	25/32	23/64	25/64
1/2	13	.400	1/2	7/8	13/32	7/16
9/16	12	.454	9/16	9/16	15/32	31/64
5/8	11	.507	5/8	1 1/16	17/32	17/32
3/4	10	.620	3/4	1 1/4	5/8	5/8
7/8	9	.731	7/8	1 7/16	3/4	23/32
1	8	.838	1	1 5/8	27/32	13/16
1 1/8	7	.939	1 1/8	1 13/16	31/32	29/32
1 1/4	7	1.064	1 1/4	2	1 3/32	1
1 3/8	6	1.158	1 3/8	2 3/16	1 3/16	1 3/32
1 1/2	6	1.283	1 1/2	2 3/8	1 9/32	1 3/16
1 5/8	5 1/2	1.389	1 5/8	2 9/16	1 13/32	1 9/32
1 3/4	5	1.490	1 3/4	2 3/4	1 1/2	1 3/8
1 7/8	5	1.615	1 7/8	2 15/16	1 5/8	1 15/32
2	4 1/2	1.711	2	3 1/8	1 3/4	1 9/16
2 1/4	4 1/2	1.961	2 1/4	3 1/2	1 31/32	1 3/4
2 1/2	4	2.175	2 1/2	3 7/8	2 3/16	1 15/16
2 3/4	4	2.425	2 3/4	4 1/4	2 7/16	2 1/8
3	3 1/2	2.629	3	4 5/8	2 5/8	2 5/16
3 1/4	3 1/2	2.879	3 1/4	5	2 29/32	2 1/2
3 1/2	3 1/4	3.100	3 1/2	5 3/8	3 1/32	2 11/16
3 3/4	3	3.317	3 3/4	5 3/4	3 11/32	2 7/8
4	3	3.567	4	6 1/8	3 19/32	3 1/16
4 1/4	2 7/8	3.798	4 1/4	6 1/2	3 13/16	3 1/4
4 1/2	2 3/4	4.027	4 1/2	6 7/8	4 1/32	3 7/16
4 3/4	2 5/8	4.255	4 3/4	7 1/4	4 9/32	3 5/8
5	2 1/2	4.480	5	7 5/8	4 1/2	3 13/16
5 1/4	2 1/2	4.730	5 1/4	8	4 3/4	4
5 1/2	2 3/8	4.953	5 1/2	8 3/8	4 31/32	4 3/16
5 3/4	2 3/8	5.203	5 3/4	8 3/4	5 7/32	4 3/8
6	2 1/4	5.423	6	9 1/8	5 7/16	4 9/16

at *a b*. This is the amount of flat given to the point of the United States standard thread, as shown at *c d*, and also at the root, as at *e f*. In other words, the United States standard thread is only three-fourths the height of a **V** thread of the same pitch; also, the United States standard bolt is stronger than a bolt of equal size with **V** threads, because the diameter at the root of the United States standard thread is greater than the diameter at the root of a **V** thread of the same pitch.

17. **Proportions.**—The various proportions of bolts and nuts having United States standard threads are given in Table II. The first three columns give the outside diameter of the bolt, the number of threads per inch, and the diameter at the root of the thread. The fourth column gives the height *h* or thickness of a rough nut, which, it will be seen, is equal to the diameter of the bolt in each case. The width *D* across the flats of a square or a hexagonal nut is given in the fifth column, and the size of tap drill is given in the sixth column. The last column gives the height *h'* of the bolt head. The width across the flats of the bolt head is the same as for the nut.

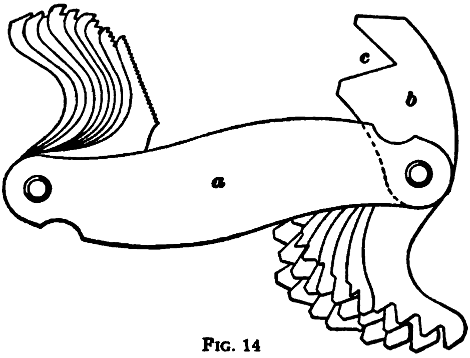


FIG. 14

18. **Gauge.**—One form of thread gauge for United States standard threads is shown in Fig. 14. It consists of a double-leaf handle *a* between whose ends are pivoted twenty-six blades, any one of which may be swung outwards for use. All but one of the blades have notches along the edge, corresponding to the pitch and shape of the various sizes of United States standard threads. The gauge may be used to test the accuracy of either external or internal threads. The

remaining blade *b* has a sharp 60° notch *c* cut in it, and the thread tool is first ground to the correct angle to fit this gauge. The flat on the end of the tool is then ground to fit the notches in the particular blade that corresponds to the pitch of thread to be cut. Similar gauges are made for use with **V** threads, metric threads, etc.

19. Cutting Tool.—The United States standard threading tool is first ground to fit the 60° notch in the gauge, and then the point is ground off to fit the flat in the gauge for the pitch of thread to be cut. A clearance of 15° is given to it. If a special gauge is not available the tool can be ground to the ordinary center gauge and the flat end gauged in a corresponding United States standard tap. United States standard threads are cut by turning the screws to the required diameter, or $\frac{1}{64}$ inch under in some cases, and then cutting the thread so that the flat has the required width. Care should be taken to try the screw in a tapped hole and to cut the thread so that it will fit only on the sides and not on the points.

20. Origin of a Standard Thread.—Originally, each manufacturer adopted his own standard as to the number of threads per inch and the form of the thread. Bolts and screws made by different firms were consequently not interchangeable, and in the case of a breakdown it was often very inconvenient to obtain repairs for machines. As manufacturing interests became specialized and shops exchanged tools and commodities, interchangeability of the parts became very desirable, and a number of leading manufacturers brought out special types of threads that they tried to have adopted.

In the year 1864, the Franklin Institute, of Philadelphia, appointed a committee to investigate and report on the subject of screw threads. They made a careful investigation, and finally recommended a system designed by Mr. William Sellers, which was later adopted by the Institute; this is the present United States standard thread.

21. Reason for Selecting Present Standard.—In determining the exact shape and pitch for a screw thread, many things had to be considered. Among these were the best angle for the sides, and whether or not the angles of the sides should be equal. When a bolt has a thread cut on its end, the strength of that bolt is reduced because of the reduced diameter at the root of the thread. It will be no stronger than a bolt having a diameter equal to the diameter at the root of the thread. It would therefore seem desirable to make the threads shallow, so as not to reduce the strength of the bolt more than necessary. The threads then might be of the general shape shown in Fig. 15.

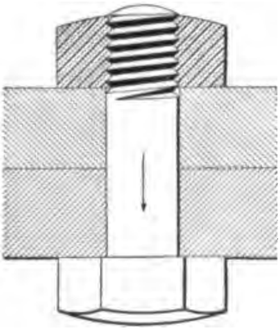
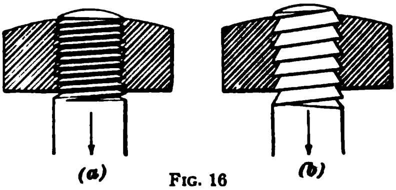


FIG. 15

22. Suppose that the bolt shown in Fig. 15 is intended to carry a load acting in the direction of the arrow. A nut shown in section holds the bolt in place. As the load is applied, the bolt tends to draw through the nut, and by so doing tends to stretch or burst it. The bursting strain on the nut depends on the angle of the side of the thread, each thread acting like a wedge in the nut. The bursting strain in this case will therefore be much greater for a given load than it would be if the threads were more acute, as shown in Fig. 16 (*a*). Besides, the great bursting strain would cause great friction on the thread, and there would be danger, in tightening the nut, that the bolt would be twisted off. It is evident, therefore, that a thread having a flat angle is not desirable. The more acute thread would so weaken the bolt that it is also undesirable.


(*a*) FIG. 16 (*b*)

23. The friction and the bursting strain on the nut might be eliminated by using a ratchet thread, as shown in Fig. 16 (*b*). This thread would be flat on the under side and would not have the bursting effect of the wedge-shaped thread. The thread would not be deep, so that the bolt would not be much reduced in strength after the thread was cut. This thread would at first seem to answer the conditions, but should the direction of the load be changed, these ideal conditions would vanish. In every case, the workman would have to consider the direction of the load before he could determine which side of the thread should be flat and which side beveled. Furthermore, the nut used for this thread would fit from one side only; if the nut were turned over, it would not go on. This consideration, with many others, led to the adoption of a thread with equal angles on each side.

24. The angle of 60° was chosen after much consideration, it being an angle easily obtained and one seeming best to answer the conditions. To give the thread durability, it was decided not to use the sharp point, as it weakened the screw. By leaving the point of the thread flat, it was possible to leave a corresponding flat at the root of the thread. The strength of the bolt was thereby increased. The points were left flat because of the ease with which the screw could be made when compared with the curved points represented by the British standard thread. The pitch of the thread for different diameters was also considered, and a standard number of threads to the inch for various diameters was adopted.

25. Formal Adoption.—The United States standard thread was authorized for use in the naval service by the government in the year 1868. In the year 1871, the Master Car Builders' Association recommended it for use in the construction of locomotives and cars. The system is now entirely used in the United States Navy, and has been adopted by manufacturers generally. It is used on commercial capscrews. It has not entirely taken the place of the **V**-thread system, however, as for very small screws and fine pitches the **V** thread is usually more desirable.

26. Variations in Diameter of Standard Bolts. The diameters of United States standard bolts vary by sixteenths, eighths, and fourths of an inch. Until recently, many makers used the same number of threads per inch, but made the diameter of the bolt $\frac{1}{64}$ or $\frac{1}{32}$ inch under or over the standard diameter; thus, a $\frac{3}{4}$-inch bolt might be $\frac{1}{64}$ inch over or under $\frac{3}{4}$ inch in diameter. Taps and dies made according to this system are still in use in some blacksmith shops. Fortunately, the confusion arising from this cause is rapidly being eliminated, and manufacturers generally are adopting the single standard system and making all their bolts of exactly the nominal diameter.

SQUARE THREAD

27. Shape.—The square thread, as its name implies, is square in section, as shown in Fig. 17. Theoretically, the space *a*, the width *b*, and the height *c* should all be equal. In practice, however, the space *a* is made slightly greater than the width *b* of the thread, or as it is termed, the *land*. It is customary to make the space one or one and one-half thousandths greater than the land, so that the threads will work freely and permit good lubrication. There is no standard relation between the diameter of the screw and the pitch. There is also no standard pitch for square threads. The square thread is used where a very strong thread is required and where a machine part has to be moved rapidly. It has practically flat bearing surfaces at right angles to its axis, thus avoiding the sidewise or bursting tendency found in the V-thread screw. Another advantage of the square thread is that it does not decrease in diameter as it wears. The wear in both nut and screw is all on the side of the thread, so these may be worn to a quarter of their original thickness and still work. A V thread would strip long before this point was reached.

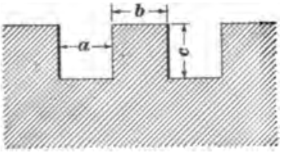


FIG. 17

28. Square-Thread Tool.—A square thread with a section of the tool used for cutting it set in its working position is shown in Fig. 18 (*a*). The square-thread tool is square-pointed, with its top face sloping slightly downwards and sidewise in the direction that the tool is feeding while cutting, as shown at *a*. The top side slope is given so that the top face will make equal angles with the two sides of the thread. The cutting part of the tool is short, as shown in the views (*b*), to give stiffness, and it is set at an angle with the vertical side of the shank of the tool so that the cutting part will follow the groove or space being cut between the threads without bearing against either side, as may be seen in view (*a*). This inclination is called the **angle of side rake,** and varies with every pitch and diameter of square thread. A right-hand tool is used for cutting a right-hand thread, and a corresponding left-hand tool is required to cut a left-hand thread. These two tools are shown in the end views (*c*) and (*d*), respectively.

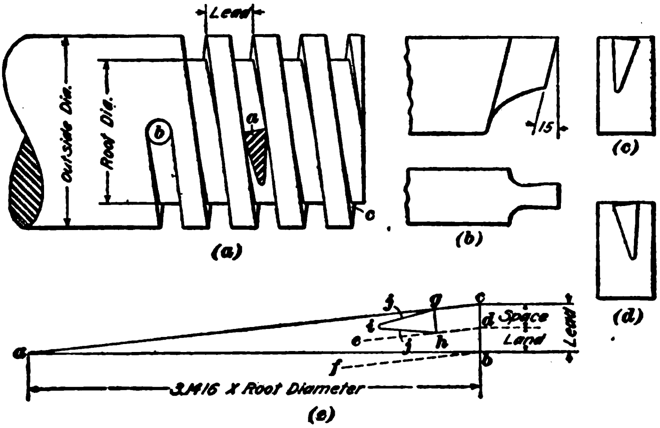


FIG. 18

29. The angle of side rake is found by drawing a straight line *a b*, Fig. 18 (*e*), equal in length to the circumference of the bolt at the root of the thread, and at one end a perpendicular *b c* equal to the lead of the thread. Then the points *a* and *c* are joined by a straight line *a c*. The angle *c a b* is the angle of side rake. The lead is equal to the sum of the width of the thread and the width of the space. The distance *c d* is made equal to the width of the space, and the dotted lines *d e* and *b f* are drawn parallel to the slanting line *a c*. The distance *g h* between the lines *a c* and *d e* is the shortest distance between the threads and represents the width of the tool at the cutting edge. The tool is shown in section in its correct angular position at *i*. In addition to its angle of side rake, it should have clearance on each side, as at *j*, so that it will not rub against the sides of the groove, which are represented by the lines *a c* and *e d*. The angle of front rake should be 15°, as shown in view (*b*). The point of the tool, for a distance of $\frac{1}{16}$ inch back from the cutting edge, should have the correct width of the thread space, and back of this point should be narrower, so as to cut a clean thread. A roughing tool slightly narrower than the finishing tool may be used to rough out a square thread to the correct root diameter.

EXAMPLE.—Find the angle of side rake for a tool to cut a square thread of $\frac{1}{2}$-inch pitch on a screw 2 inches in diameter.

SOLUTION.—The method is shown by the diagrams in Fig. 18 (*a*) and (*e*) which are half size. The pitch is $\frac{1}{2}$ in., and the width of the space is half the pitch, or $\frac{1}{4}$ in., which is also the depth of the space. The root diameter is equal to the outside diameter minus twice the depth of the space, or $2-(2\times\frac{1}{4})=2-\frac{1}{2}=1\frac{1}{2}$ in. The distance *a b* in (*e*) is therefore made $3.1416\times1\frac{1}{2}=4.71$ in. The distance *b c* is laid off vertically equal to $\frac{1}{2}$ in., or the lead, and the line *c a* is drawn. Then the angle *c a b* is the required angle of side rake to be given to the tool. Ans.

30. Cutting Square Threads.—A square thread is often required to stop abruptly in the stock, so a hole *b*, Fig. 18 (*a*), is drilled at the place where the thread will end, into which the tool can run and cut off the chip. When cutting a square thread, the tool is first set so that it will come central with the drilled hole at the end of the cut. The lathe is stopped when the tool is within a turn of the hole and the belt is pulled around by hand until the chip is cut off. The tool is withdrawn and the operation is repeated until the thread is cut to the required depth. The finishing tool is then carefully set square with the axis and level with the center and light cuts are taken until the correct depth is reached. Lard oil is always applied to the tool and the work when cutting the harder metals. After the thread is cut it will be found that, at the point where the tool cuts only on one side as it starts into the cut, as at *c*, the thread will be thicker than where the tool cuts and is supported on both sides. This high side of the thread should be carefully filed down to the same thickness as the rest of the thread, after which it should be well oiled and tried in the nut. If the thread is too tight it can be eased off by running a thin file along its side until it fits correctly.

ACME THREAD

31. Shape.—The sides of the Acme thread, shown in section in Fig. 19, are inclined 14½°, making the included angle 29°. The depth of the thread is the same as for a square thread of the same pitch. The top of the thread does not touch the bottom of the space in the nut. This opening represents the clearance, which is provided to insure a perfect fit on the sides of the thread. The Acme thread is better suited than the square thread for a feed-screw on which a split nut is used, as on the lead screw of a lathe, because the parts of the nut will engage easier than they would with a square thread. Another advantage of the Acme thread is that it is easier to tap holes for it than for square threads, as the teeth of Acme taps are less likely to break.

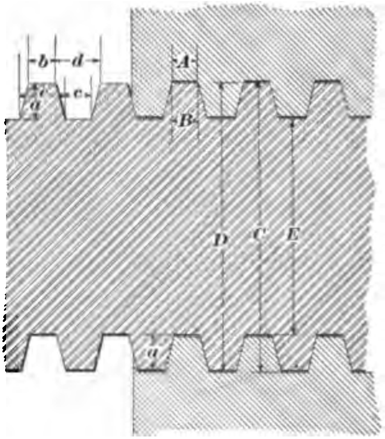


FIG. 19

32. Proportions.—The various dimensions of the Acme screw thread are given in Table III, in which the letters at the tops of the columns refer to the corresponding dimensions shown in Fig. 19. The width *A* of the space at the bottom of the thread in the nut is .0052 inch less than the width *B* of the point of the thread, which is equal to the dimension *b*. The point of the Acme thread tool therefore must have a width equal to *A*. The dimension *C* is the diameter of the tap required, which is .02 inch larger than *D*, the outside diameter of the screw. The root diameter *E* is equal to the diameter *D* minus twice the depth *a* of the thread.

TABLE III

ACME STANDARD SCREW THREAD

Number of Threads per Inch	Depth of Thread Inch *a*	Thickness at Top of Thread Inch *b*	Width of Space at Bottom of Thread Inch *c*	Width of Space at Top of Thread Inch *d*	Thickness at Root of Thread Inch *e*
1	.5100	.3707	.3655	.6293	.6345
1⅓	.3850	.2780	.2728	.4720	.4772
1½	.3433	.2471	.2419	.4195	.4247
2	.2600	.1853	.1801	.3147	.3199
3	.1767	.1235	.1183	.2098	.2150
4	.1350	.0927	.0875	.1573	.1625
5	.1100	.0741	.0689	.1259	.1311
6	.0933	.0618	.0566	.1049	.1101
7	.0814	.0529	.0478	.0899	.0951
8	.0725	.0463	.0411	.0787	.0839
9	.0655	.0413	.0361	.0699	.0751
10	.0600	.0371	.0319	.0629	.0681

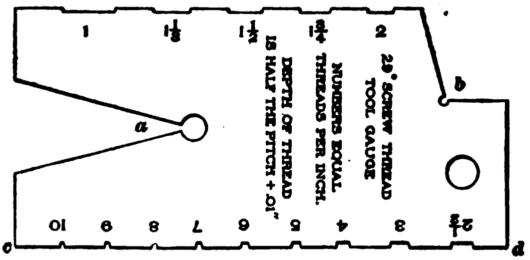

1
1⅓
1½
1¾
2
29° SCREW THREAD TOOL GAUGE
NUMBERS EQUAL THREADS PER INCH.
DEPTH OF THREAD IS HALF THE PITCH + .01"
a
b
c
d
10
9
8
7
6
5
4
3
2½

FIG. 20

33. Cutting Acme Threads.—The cutting operations followed in roughing and finishing the Acme thread do not differ materially from those followed in cutting a square thread. The Acme thread tool is ground or filed to the **V** notch *a* in the 29° thread-tool gauge shown in Fig. 20. Its point is then made flat to fit the width of the slot opposite the number denoting the pitch of thread to be cut. The end of the gauge opposite the slot *a* has a 14½° angle *b* that is used in setting the tool. The back edge *c d* of the gauge is held against the work or the dead spindle and the tool is adjusted to fit the angle *b* in the front of the gauge.

BRITISH STANDARD THREAD

34. Origin.—In the year 1861, Sir Joseph Whitworth, of England, proposed a system of standards for screw threads to overcome the inconveniences arising in England by the use of a great number of individual systems, each builder or manufacturer having had his own standard up to that time. The system that he introduced is now the standard thread used by British manufacturers, and the same form has been adopted very largely throughout Europe. The rounding of the top and bottom of the thread has certain very desirable features, as it adds greatly to the strength and durability of the screw and does away with the sharp corners, which are more liable to be nicked or bruised.

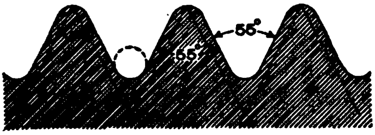


FIG. 21

American manufacturers who are accustomed to the United States standard consider the difficulty of keeping up to standard the necessary tools for producing these curved points and roots a sufficient argument against the adoption of the British standard screw thread in this country.

35. Shape.—The exact shape of the British standard thread is shown in Fig. 21 by the full lines, and a **V** thread of the same pitch is indicated by the dotted lines. The British standard thread, also called the *Whitworth thread*, has straight sides that form an angle of 55° with each other, and the point and the root are rounded. The curve at the point is part of a circle that has a radius equal to .137 times the pitch of the thread, and the curve at the root has the same radius. The sides of the threads are tangent to the circles drawn at the root and the point. The depth of the British standard thread is .64 times that of the sharp, or **V**, thread of equal pitch, and it is therefore the stronger. The numbers of threads per inch for bolts of various sizes with British standard threads are given in Table IV.

TABLE IV

BRITISH STANDARD, OR WHITWORTH, SCREW THREADS

Diameter of Bolt Inch	Number of Threads per Inch	Diameter of Bolt Inches	Number of Threads per Inch	Diameter of Bolt Inches	Number of Threads per Inch	Diameter of Bolt Inches	Number of Threads per Inch
1/4	20	7/8	9	2	4 1/2	3 1/4	3 1/4
5/16	18	15/16	9	2 1/8	4 1/2	3 3/8	3 1/4
3/8	16	1	8	2 1/4	4	3 1/2	3 1/4
7/16	14	1 1/8	7	2 3/8	4	3 5/8	3 1/4
1/2	12	1 1/4	7	2 1/2	4	3 3/4	3
9/16	12	1 3/8	6	2 5/8	4	3 7/8	3
5/8	11	1 1/2	6	2 3/4	3 1/2	4	3
11/16	11	1 5/8	5	2 7/8	3 1/2		
3/4	10	1 3/4	5	3	3 1/2		
13/16	10	1 7/8	4 1/2	3 1/8	3 1/2		

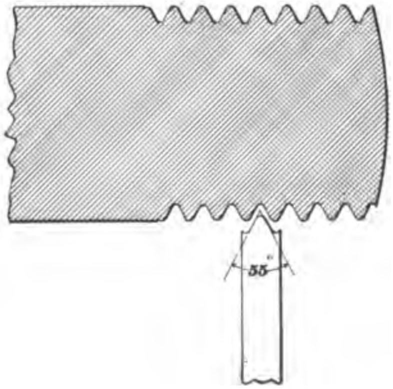


Fig. 22

36. Cutting.—The operation of cutting British standard threads is similar to that used for United States standard threads. The difference in thread is due to the shape of the tool. Every pitch of thread requires a tool of particular size and shape, the same as the United States standard; but because of the curved point and root of the thread, the tool is much more difficult to make. Fig. 22 shows the plan of a tool as it is applied to the work. The point is rounded and round shoulders are formed on the tool, to form the round points of the threads. These tools are thus in reality *forming tools*, and are sharpened by grinding on the top face. They are formed by using a hob, which is an accurately threaded screw of the required diameter and pitch or lead of thread. This screw is fluted, to form cutting edges and a place for chips in front of each cutting edge. The teeth formed by the flutes are backed off, after which the hob is hardened and tempered. A dog is clamped on the hob, which is held between the lathe centers while the blank tool is held in the tool post. As the hob revolves, the tool blank is fed up to it; at the same time it is fed along by the lead screw. By repeating these operations, as in cutting a screw, the blank is soon formed into a threading tool. After hardening, it is ready to be used to cut the desired screw.

OTHER THREADS

37. Worm Thread.—The worm thread is used to transmit motion, and it must therefore have a large amount of wearing surface on the sides of the threads. The angle of the worm thread is 29°, as in the Acme thread; but the worm thread is made about one-third deeper than the Acme thread of the same pitch, to increase the wearing surface. The tool for cutting the worm thread must have enough side rake to follow the lead of the thread being cut. The worm-thread tool should be filed or ground to a worm-thread tool gauge.

38. Automobile Threads.—The Society of Automobile Engineers has adopted a standard of screw threads that is better suited to automobile work than either the United States standard or the V thread. The screws used in automobile work are of finer pitch than the United States standard, because the screws and bolts are of as small diameter as they may be made with safety, and the fine thread does not need to be cut so deep as the coarser pitch, thus making the screw stronger. Another reason is that most of the threads are cut in hard, tough materials that do not require so coarse a pitch of thread as does cast iron. The automobile thread is of the same shape as the United States standard, and the numbers of threads per inch for the various sizes are given in Table V. This thread was formerly known as the A. L. A. M. thread, or Association of Licensed Automobile Manufacturers' standard thread.

TABLE V

SOCIETY OF AUTOMOBILE ENGINEERS' STANDARD SCREWS

Diameter of Screw Inch	Number of Threads per Inch	Diameter of Screw Inches	Number of Threads per Inch
$\frac{1}{4}$	28	$\frac{3}{4}$	16
$\frac{5}{16}$	24	$\frac{7}{8}$	14
$\frac{3}{8}$	24	1	14
$\frac{7}{16}$	20	$1\frac{1}{8}$	12
$\frac{1}{2}$	20	$1\frac{1}{4}$	12
$\frac{9}{16}$	18	$1\frac{3}{8}$	12
$\frac{5}{8}$	18	$1\frac{1}{2}$	12
$\frac{11}{16}$	16		

39. Ratchet Thread.—In Fig. 16 (*b*) is shown the ratchet thread, a special thread used to take up axial pressure on the flat sides. It is employed in a modified form to take up the end thrust in breech blocks in large guns.

40. Metric Thread.—The metric thread, also called the international thread, is the one used in France, and to some extent in other countries. In shape it is similar to the United States standard thread, but the pitch is not the same as for United States standard bolts of the same size; therefore, to cut metric screws on a lathe having a lead screw with a known number of threads per inch, change gears known as *adapting gears* must be used. The proportions of metric threads are given in Table VI, in both metric and English units.

TABLE VI

METRIC STANDARD SCREW THREADS

Diameter of Bolt		Pitch		Diameter at Root of Thread		Width of Flat	
Millimeters	Inches	Millimeter	Inch	Millimeters	Inches	Millimeter	Inch
3	.1181	.5	.0197	2.35	.0925	.06	.0024
4	.1575	.75	.0295	3.03	.1193	.09	.0035
5	.1969	.75	.0295	4.03	.1587	.09	.0035
6	.2362	1.0	.0394	4.70	.1850	.13	.0051
7	.2756	1.0	.0394	5.70	.2244	.13	.0051
8	.3150	1.0	.0394	6.70	.2638	.13	.0051
8	.3150	1.25	.0492	6.38	.2512	.16	.0063
9	.3543	1.0	.0394	7.70	.3031	.13	.0051
9	.3543	1.25	.0492	7.38	.2906	.16	.0063
10	.3937	1.5	.0591	8.05	.3169	.19	.0075
11	.4331	1.5	.0591	9.05	.3563	.19	.0075
12	.4724	1.5	.0591	10.05	.3957	.19	.0075
12	.4724	1.75	.0689	9.73	.3831	.22	.0087
14	.5512	2.0	.0787	11.40	.4488	.25	.0098
16	.6299	2.0	.0787	13.40	.5276	.25	.0098
18	.7087	2.5	.0984	14.75	.5807	.31	.0122
20	.7874	2.5	.0984	16.75	.6594	.31	.0122
22	.8661	2.5	.0984	18.75	.7382	.31	.0122
24	.9449	3.0	.1181	20.10	.7913	.38	.0150
26	1.0236	3.0	.1181	22.10	.8701	.38	.0150
27	1.0630	3.0	.1181	23.10	.9094	.38	.0150
28	1.1024	3.0	.1181	24.10	.9488	.38	.0150
30	1.1811	3.5	.1378	25.45	1.0020	.44	.0173
32	1.2598	3.5	.1378	27.45	1.0807	.44	.0173
33	1.2992	3.5	.1378	28.45	1.1201	.44	.0173
34	1.3386	3.5	.1378	29.45	1.1594	.44	.0173
36	1.4173	4.0	.1575	30.80	1.2126	.50	.0197
38	1.4961	4.0	.1575	32.80	1.2913	.50	.0197
39	1.5354	4.0	.1575	33.80	1.3307	.50	.0197
40	1.5748	4.0	.1575	34.80	1.3701	.50	.0197
42	1.6535	4.5	.1772	36.15	1.4232	.56	.0220
44	1.7323	4.5	.1772	38.15	1.5020	.56	.0220
45	1.7717	4.5	.1772	39.15	1.5413	.56	.0220
46	1.8110	4.5	.1772	40.15	1.5807	.56	.0220
48	1.8898	5.0	.1969	41.51	1.6342	.63	.0248
50	1.9685	5.0	.1969	43.51	1.7130	.63	.0248
52	2.0472	5.0	.1969	45.51	1.7917	.63	.0248
56	2.2047	5.5	.2165	48.86	1.9236	.69	.0272
60	2.3622	5.5	.2165	52.86	2.0811	.69	.0272
64	2.5197	6.0	.2362	56.21	2.2130	.75	.0295
68	2.6772	6.0	.2362	60.21	2.3705	.75	.0295
72	2.8346	6.5	.2559	63.56	2.5024	.81	.0319
76	2.9921	6.5	.2559	67.56	2.6598	.81	.0319
80	3.1496	7.0	.2756	70.91	2.7917	.88	.0346

CUTTING SCREW THREADS ON LATHE

CALCULATING CHANGE GEARS

41. Adapting Engine Lathe for Screw Cutting. The engine lathe is made suitable for cutting threads by four motions, namely, a lead screw to move the carriage along the bed, a set of change gears to make the lead screw turn faster or slower than the spindle, a feed-gear reversing mechanism, and a means of reversing the motion of the spindle and the work. The lead screw is driven at any required speed with respect to the spindle speed, through a train of fixed and change gears, from the live spindle. It usually has two, three, four, six, or eight threads per inch, although various other numbers of threads are used for specific purposes.

42. Change-Gear Stack.—Each ordinary engine lathe has a set, or *stack*, of change gears, which are made in a regular order of sizes, the smallest having about twenty and the largest about one hundred and twenty teeth. The various gears in the set vary by a regular number of teeth, as 4, 5, 6, or 7; that is, if a set of gears is found to contain gears having 20, 24, 28, 32, 36 teeth, etc., the gears are said to vary by 4, and the number of teeth in each gear is divisible by 4. If the gears have 18, 24, 30, 36, 42, etc. teeth, they are said to vary by 6, and the number of teeth in each gear in the set is divisible by 6. If the set has gears having 21, 28, 35, 42, 49, etc. teeth, they vary by 7, and the number of teeth in each gear in the set is divisible by 7. The smallest would be 21 and the largest 112 or 119. Each stack of change gears also has two gears, near the middle of the range, that are of equal size, as two gears of 44, 48, or 56 teeth, which are used to cut a thread of the same pitch as the lead screw.

43. Reversing Mechanisms.—The direction in which the lead screw turns is determined by adding or removing a gear from the train connecting the spindle with the lead screw. The tumbler gear is used for this purpose, and also when changing from right-hand to left-hand threading. The direction of rotation of the work is reversed by the countershaft or by operating the reversing gear in the main drive of the geared head, to return the carriage and the tool to the starting point for a fresh cut.

44. **Arrangement of Change Gearing.**—There are two kinds of lathes used for cutting threads, known as *simple-geared lathes*, in which two change gears are calculated, and *compound-geared lathes*, in which four gears are calculated. A simple-geared lathe is shown in Fig. 23 and a compound-geared lathe in Fig. 24. The spindle of the engine lathe may make one or more turns to one turn of the lead screw. The number of turns is regulated by the size of the spindle and stud gears *b* and *d*, Fig. 23. If the gears are of the same size, the spindle and the lead screw will turn at the same rate;

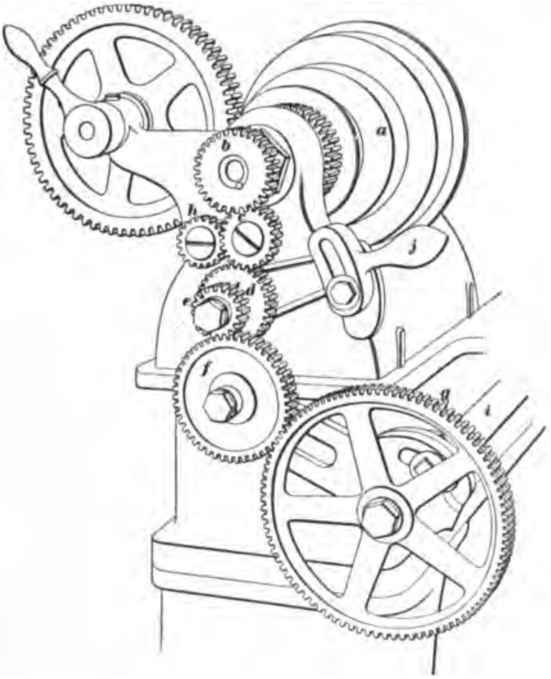


Fig. 23

but if the spindle gear has only half as many teeth as the stud gear, the stud will turn once to two turns of the spindle. If the spindle and stud gears are equal and two change gears of the same size are placed on the stud and lead screw in the places of the stud and screw gears *e* and *g*, Fig. 23, the lead screw will make the same number of turns as the spindle and the screw thread cut will have the same pitch as the lead screw. If, however, the stud has its fixed gear *d* twice as large as the spindle gear *b* and equal change gears are used, the thread cut will have twice as many threads per inch as the lead screw.

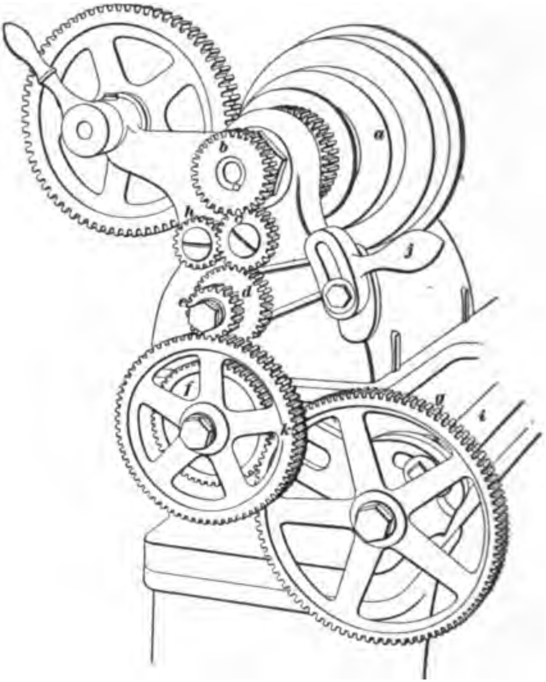


FIG. 24

45. Lead of Lathe.—The distance that the carriage will travel along the bed during one complete turn of the work, when gears of the same size are used on the stud and the lead screw, is the lead of a lathe. If the gear on the spindle is of the same size as the gear on the stud, so that they turn at the same speed, the lead of the lathe is equal to the pitch or lead of the lead screw; but if the gear on the stud is twice the size of the gear on the spindle, the lead of the lathe will be only half as great as before. When the fixed gears on the spindle and on the stud are equal—that is, when the gears *b* and *d*, Figs. 23 and 24, are equal—the lathe is said to be geared 1 to 1; but when the stud gear *d* has twice as many teeth as the spindle gear *b*, the lathe is said to be geared 1 to 2. When a lathe is geared 1 to 1, the reciprocal of the lead of the lathe is the same as the *actual* number of threads per inch of the lead screw; that is, if a lathe geared 1 to 1 is found to have a lead of $\frac{1}{4}$ inch, the lead screw has four threads per inch. If the same lathe were geared 1 to 2, the lead of the lathe would be $\frac{1}{8}$ inch, and the reciprocal of this lead, or 8 would be the *effective* number of threads per inch of the lead screw; that is, the effect would be the same as though the lead screw had eight threads per inch and the lathe was geared 1 to 1.

46. To find the lead of a lathe, change gears of equal sizes are put on the stud and the lead screw. The spindle is then turned forwards enough to take up the backlash in the gearing and the lead screw nut. The position of the large cone gear in relation to the head is marked on the head, and a rule is placed on the lathe bed with its end against the carriage. Exactly one turn is then given to the spindle and the distance between the end of the rule and the carriage is measured. This is the lead of the lathe. Some lathes are built with a cone, usually of three gears of different size, any one of which may be used to get a different speed ratio between the spindle and screw. The shaft on which they are carried is hollow. A pin carrying a key passes through the shaft, and when *in*, *out*, or *central*, a different gear is engaged by the key, thus giving three pitches that can be assumed for the lead screw.

47. Calculating Simple Change Gears.—If the desired number of threads can be cut by the use of simple gearing, the sizes of the change gears required may be found by the following rule:

Rule.—*Form a fraction whose numerator is the reciprocal of the lead of the lathe and whose denominator is the number of threads per inch to be cut; then multiply each by the difference of the numbers of teeth in successive gears of the change-gear stack, or a multiple of that difference. The numerator and denominator of the resulting fraction will then denote the numbers of teeth in the required change gears.*

The gear having the number of teeth corresponding to the numerator of the fraction thus found should be placed on the stud, as at *e*, Fig. 23, and the gear corresponding to the denominator should be placed on the lead screw, or at *g*.

48. Calculating Compound Change Gears.—The following rule should be used to find the sizes of the change gears required to cut a given thread by the use of compound gearing:

Rule.—*Form a fraction whose numerator is the reciprocal of the lead of the lathe and whose denominator is the number of threads per inch to be cut; then multiply each by the difference of the numbers of teeth on successive gears of the change-gear stack. Factor the fraction thus found into two other fractions, and then multiply the numerator and denominator of each of these latter fractions by some number that will give products equal to numbers of teeth in gears in the gear stack. The numbers thus found will be the numbers of teeth in the required change gears.*

After finding the two fractions whose product is equal to the first fraction, it may be necessary to make one or more trials in multiplying each by some number, before the result will show numbers that correspond to the numbers of teeth in the change-gear stack. The gears corresponding to the numerators of these fractions are placed on the stud and the idler stud, respectively, or at *e* and *f*, Fig. 24. The gears corresponding to the denominators are placed on the idler stud and the lead screw; or at *k* and *g*, respectively.

49. Examples of Change-Gear Calculations.—The rules given in Arts. 47 and 48 cover all cases in which it is necessary to calculate the sizes of change gears. To illustrate how these rules are applied in solving various problems, the following examples and solutions are given:

Example 1.—A lathe that is geared 1 to 1 has a lead screw with 4 threads per inch, and the gears in the gear stack vary by 6 teeth from 18 to 120. What simple change gears should be used to cut a screw with 8 threads per inch?

Solution.—As the lathe is geared 1 to 1, the lead is equal to the pitch of the lead screw, or $\frac{1}{4}$ in., and the reciprocal of the lead is therefore $1 \div \frac{1}{4} = 4$. Applying the rule of Art. 47, the fraction is $\frac{4}{8}$. The difference between the numbers of teeth of two successive gears in the stack is 6. Then, $\frac{4\times6}{8\times6}=\frac{24}{48}$. The required change gears are therefore those having 24 teeth and 48 teeth. Ans.

Example 2.—Assuming that the lathe in example 1 is geared 1 to 2, find the change gears required.

Solution.—As the lathe is geared 1 to 2, the lead of the lathe is half the pitch of the lead screw, or $\frac{1}{2}\times\frac{1}{4}=\frac{1}{8}$ in. The reciprocal of $\frac{1}{8}$ is 8. Applying the rule of Art. 47, then, $\frac{8\times6}{8\times6}=\frac{48}{48}$. The change gears required therefore have 48 teeth each. Ans.

Example 3.—A lathe geared 1 to 2 has a gear stack ranging from 18 to 120, varying by 6 teeth, and the lead screw has 5 threads per inch. What compound change gears may be used to cut a screw having 25 threads per inch?

Solution.—As the gearing is compound, four gears are to be found. The lathe is geared 1 to 2, so that the lead of the lathe is $\frac{1}{10}$ in., and the reciprocal of $\frac{1}{10}$ is 10. Applying the rule of Art. 48, $\frac{10\times6}{25\times6}=\frac{60}{150}$. Factoring this fraction, $\frac{60}{150}=\frac{12\times5}{15\times10}=\frac{12}{15}\times\frac{5}{10}$. Then, $\frac{12\times6}{15\times6}=\frac{72}{90}$, and $\frac{5\times6}{10\times6}=\frac{30}{60}$. As the change-gear stack has gears with 72, 90, 30, and 60 teeth, these may be used as the four change gears. Ans.

Example 4.—It is desired to cut 1 thread per inch on a lathe having a lead screw with 6 threads per inch. If the gear stack varies by 5 teeth from 20 to 100 and the lathe is geared 1 to 1, what four change gears may be used?

Solution.—The lead of the lathe is the same as the pitch of the lead screw, or $\frac{1}{6}$ in., because the lathe is geared 1 to 1. The reciprocal of $\frac{1}{6}$ is 6. Applying the rule of Art. **48**, $\frac{6\times 5}{1\times 5}=\frac{30}{5}$. But, $\frac{30}{5}=\frac{10\times 3}{5\times 1}=\frac{10}{5}\times\frac{3}{1}$. Then, $\frac{10\times 5}{5\times 5}=\frac{50}{25}$, and $\frac{3\times 20}{1\times 20}=\frac{60}{20}$. As there are gears of 50, 25, 60, and 20 teeth in the stack, these four gears will cut the required thread. Ans.

Example 5.—A screw having $6\frac{2}{3}$ threads per inch is to be cut on a lathe geared 1 to 2, with a lead screw having 8 threads per inch. If the gear stack has gears varying by 6 teeth from 18 to 120, what two change gears may be used?

Solution.—As two gears are to be used, simple gearing is to be employed, and as the lathe is geared 1 to 2, the lead is half the pitch of the lead screw, or $\frac{1}{16}$ in. The reciprocal of $\frac{1}{16}$ is 16. Applying the rule of Art. **47**, $\frac{16}{6\frac{2}{3}}=\frac{16}{\frac{20}{3}}=\frac{16}{1}\times\frac{3}{20}=\frac{48}{20}$. As the fraction $\frac{48}{20}$ cannot be multiplied by any whole number that will give gears contained in the stack, it is necessary to reduce it first to lower terms; thus, $\frac{48}{20}=\frac{12}{5}$. Then, multiplying this by the number of teeth by which the gears vary, $\frac{12\times 6}{5\times 6}=\frac{72}{30}$; that is, the required gears have 72 and 30 teeth. Ans.

Example 6.—A lathe geared 1 to 1 has a lead screw with 6 threads per inch and a gear stack varying by 6 teeth from 18 to 120. What change gears must be used to cut $3\frac{1}{4}$ threads per inch, if compound gearing is employed?

Solution.—The lead of the lathe is $\frac{1}{6}$ in. or the pitch of the lead screw, because the lathe is geared 1 to 1. The reciprocal of $\frac{1}{6}$ is 6. Applying the rule of Art. **48**, $\frac{6}{3\frac{1}{4}}=\frac{6}{\frac{13}{4}}=\frac{6}{1}\times\frac{4}{13}=\frac{24}{13}$. Then, $\frac{24}{13}\times\frac{6}{6}=\frac{144}{78}$. But, $\frac{144}{78}=\frac{16}{13}\times\frac{9}{6}$. Then, $\frac{16\times 6}{13\times 6}=\frac{96}{78}$, and $\frac{9\times 6}{6\times 6}=\frac{54}{36}$. Hence, the four change gears have 96, 78, 54, and 36 teeth. Ans.

50. Sometimes the pitch of the thread to be cut is stated, instead of the number of threads per inch. In a case of this kind all that is necessary is to find the number of threads per inch corresponding to the pitch, and then to apply the rule. The number of threads per inch is equal to the reciprocal of the pitch; that is, it is equal to 1 divided by the pitch. Thus, if it is desired to cut a thread of $\frac{3}{8}$-inch pitch, the lathe should be geared to cut $1\div\frac{3}{8}=1\times\frac{8}{3}=\frac{8}{3}=2\frac{2}{3}$ threads per inch.

The following examples and solutions will serve to make these points clear:

EXAMPLE 1.—A thread of $\frac{3}{8}$-inch pitch is to be cut on a lathe geared 1 to 1 and having a lead screw with 6 threads per inch. Find two change gears that will cut the required pitch, if the gear stack has gears from 18 to 120 teeth varying by 6 teeth.

SOLUTION.—As the lathe is geared 1 to 1 and the lead screw has 6 threads per inch, the lead of the lathe is $\frac{1}{6}$ in., and the reciprocal of $\frac{1}{6}$ is 6. If the pitch is $\frac{3}{8}$ in., the number of threads per inch is $1 \div \frac{3}{8} = 1 \times \frac{8}{3} = \frac{8}{3} = 2\frac{2}{3}$. Applying the rule of Art. **47**, $\frac{6}{2\frac{2}{3}} = \frac{6}{1} \div \frac{8}{3} = \frac{6}{1} \times \frac{3}{8} = \frac{18}{8}$. Then, $\frac{18 \times 6}{8 \times 6} = \frac{108}{48}$; that is, the change gears may have 108 and 48 teeth. Ans.

EXAMPLE 2.—A lathe geared 1 to 2 has a lead screw of $\frac{3}{4}$-inch pitch and a gear stack ranging from 24 to 144 teeth by 12. What two change gears may be used to cut a screw of 4 threads per inch?

SOLUTION.—As the lathe is geared 1 to 2, the lead of the lathe is $\frac{1}{2} \times \frac{3}{4} = \frac{3}{8}$ in., and the reciprocal of $\frac{3}{8}$ is $\frac{8}{3} = 2\frac{2}{3}$. Applying the rule of Art. **47**, $\frac{2\frac{2}{3}}{4} = \frac{8}{3} \div 4 = \frac{8}{3} \times \frac{1}{4} = \frac{8}{12}$. Then, $\frac{8 \times 12}{12 \times 12} = \frac{96}{144}$; that is, the change gears have 96 and 144 teeth. Ans.

EXAMPLE 3.—The lead screw of a lathe geared 1 to 1 has $\frac{5}{8}$-inch pitch and the gear stack varies by 5 teeth from 20 to 120. Find two change gears to cut a thread of $2\frac{3}{4}$ inches pitch.

SOLUTION.—If the pitch is $\frac{5}{8}$ in., and the lathe is geared 1 to 1, the lead of the lathe is equal to the lead screw pitch, or $\frac{5}{8}$ in. The reciprocal of $\frac{5}{8}$ is $\frac{8}{5} = 1\frac{3}{5}$. If the screw to be cut has a pitch of $2\frac{3}{4}$ in., it has $1 \div 2\frac{3}{4} = 1 \times \frac{4}{11} = \frac{4}{11}$ thread per in. Applying the rule of Art. **47**, $\frac{1\frac{3}{5}}{\frac{4}{11}} = \frac{8}{5} \div \frac{4}{11} = \frac{8}{5} \times \frac{11}{4} = \frac{88}{20}$. This fraction cannot be multiplied by any whole number that will give gears contained in the stack, so it must first be reduced to lower terms; that is, $\frac{88}{20} = \frac{22}{5}$. Then, $\frac{22 \times 5}{5 \times 5} = \frac{110}{25}$; that is, the required change gears have 110 and 25 teeth. Ans.

51. Change Gears for Metric Threads.—It may be necessary to cut metric threads—that is, threads made by the metric system of measurements—on a lathe having a lead screw made to inch units, or to cut threads per inch on a lathe having a metric lead screw. The change gears required may be found by the rules already given; but in order to apply these rules, it is necessary first to change the metric threads into the corresponding threads per inch. A meter is 39.37 inches, and a millimeter is .03937 inch; hence, millimeters may be changed to inches by multiplying by .03937 and inches to millimeters by dividing by .03937. The following example and solution will show the method of procedure to be used:

EXAMPLE.—It is desired to cut a metric screw having a pitch of 2 millimeters on a lathe that has a lead screw with 8 threads per inch. Find the change gears required, if the lathe is geared 1 to 1 and the gear stack ranges by 5 teeth from 20 to 100.

SOLUTION.—A pitch of 2 mm. is the same as $2\times.03937=.07874$ in. The number of threads per inch to be cut is therefore $1\div.07874=12.7$. The lead of the lathe is equal to the pitch of the lead screw, or $\frac{1}{8}$ in., as the lathe is geared 1 to 1. The reciprocal of $\frac{1}{8}$ is 8. Applying the rule of Art. 48, $\frac{8\ \times10}{12.7\times10}=\frac{80}{127}$. There is an 80-tooth gear in the gear stack, and if a 127-tooth gear is not on hand, it must be made. The two gears therefore contain 80 and 127 teeth. Ans. The 80-tooth gear goes on the stud and the 127-tooth gear on the lead screw.

Compound gearing may be used instead of simple gearing, if desired. For instance, in the example just given, the fraction is $\frac{80}{127}$, which, when factored, becomes $\frac{80}{127}=\frac{40\times2}{127\times1}=\frac{40}{127}\times\frac{2}{1}$. Then, one pair of gears will have 40 and 127 teeth. For the other pair, $\frac{2\times25}{1\times25}=\frac{50}{25}$, or gears of 50 and 25 teeth may be used. A 127-tooth gear, known as a *translating gear*, is always used in cutting metric threads with a lathe having a lead screw based on inch units, because 127 is the smallest whole number of millimeters that is practically equal to a whole number of inches; for $127\times.03937=4.99999$, which is practically 5.

CUTTING SCREW THREADS

52. Operation of Cutting Threads.—The piece to be threaded should have the center holes well cleaned and oiled. A dog is clamped securely on the end opposite the one to be threaded and the work is adjusted to turn freely between the centers. The part to be threaded is turned to a uniform diameter, which often is $\frac{1}{64}$ inch under size so that there will be no danger of the threads bearing on the points. The thread tool is set square to and at the height of the axis of the work and clamped securely. The change gears are calculated, if necessary, placed in position, and clamped so that nothing can slip while the thread is being cut. The feed should be set to move the carriage toward the headstock to cut a right-hand thread, and in the opposite direction to cut a left-hand thread. The tumbling gear may be employed for this purpose. The tool is fed in until the point just touches the work as the lathe runs forward. A light cut is traced on the work to the end of the thread, where the lathe is stopped.

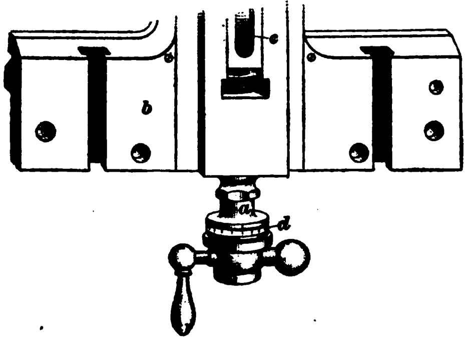


FIG. 25

53. After the first cut is made on the work with the point of the tool, it is good practice to hold a scale against the threads and count the number to the inch to see whether the lathe is cutting correctly. If a mistake is discovered it can be rectified; if the error of pitch is not discovered until the thread is cut, there is no remedy. If correct, the stop is set or the graduated sleeve on the cross-feed screw is set to zero. The tool is then drawn back by a turn or two of the cross-feed screw and the lathe reversed to run the carriage back to the starting point. The tool is fed in the required distance for another cut and run over the thread as before. These operations are repeated until the thread is cut to such a depth that it will screw into a nut or tapped hole and show a good bearing on the sides of the threads. The last, or smoothing, cuts should be very light.

54. Graduated Dial on Cross-Feed.—The increased depth of each succeeding cut, when forming a screw thread, may be regulated by the attachment shown in Fig. 25. It consists of a sleeve *a* that is firmly fixed in the saddle *b* and that forms a bearing for the cross-feed screw *c*. A graduated dial *d* is placed on the outer end of the stem of the feed-screw and is made adjustable, so that its zero can be set in line with a mark on the sleeve *a* when the point of the threading tool is just touching the work. At each succeeding cut the screw *c* is turned more, and the dial *d* shows the depth to which the tool cuts. The dial is graduated to read in sixty-fourths or in thousandths of an inch.

55. Screw Stop.—The older lathes commonly had a thread stop clamped on the cross-slide, or some similar method was used to gauge the depth of cut when threading. Such a stop is arranged on the cross-slide, as shown at *b*, Fig. 26. The stop is rigidly fastened to the slide by tightening the setscrew *a*. An adjusting screw *s*, with a large shoulder and a knurled head, passes loosely through the stop and screws into the tool block *t*. When the stop is adjusted as shown, the tool and tool block can be moved away from the work, as the screw *s* is not threaded in the stop-block *b*. When the block is moved forwards, it can move only until the head of the screw *s* comes against the stop. After the tool has passed over the work and it is desired to take a deeper cut, the stop-screw *s* is unscrewed a partial turn; the tool is thus allowed to advance slightly, depending on the amount the screw is turned.

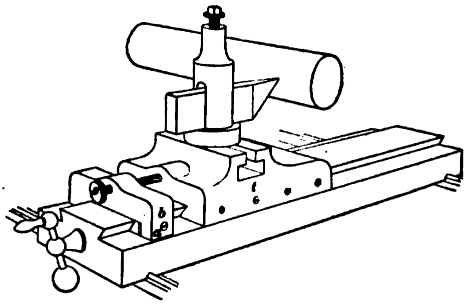


FIG. 26

56. When cutting inside threads, the stop shown in Fig. 26 may be used by taking the screw out of the stop and putting it in the tool block so that it comes between the tool block and the stop. For inside screw cutting, it is necessary to move the tool in an opposite direction, to take the tool out of the cut, from that required in outside screw cutting. The stop-screw must therefore be so adjusted that the head of the screw comes against the stop. Deeper cuts may be made by turning the screw into the tool block.

57. Sidewise Spring of Thread Tool.—When the thread tool starts into the cut, there is a tendency for the tool to spring to one side, away from the work, before both sides are supported in the cut, and for the first half revolution the cutting is done only by one edge. The tool will thus be sprung away from the cut. After the work has made a complete revolution, the pressures on the two sides of the tool balance each other and the tendency to spring sidewise is gone. This spring of the tool will make the first thread on the work slightly thicker than the others, so that in testing the work the nut will be found to be tight on the end, and after it has passed over this thick thread, the fit will be loose. This condition may be avoided by taking two or three light cuts over the first thread and cutting it a little deeper than the following threads, when cutting V threads. If a square thread is being cut, the high side of the thread must be so filed that it will be of the same thickness as the thread where both sides of the tool were in the cut.

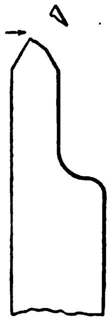


Fig. 27

58. Breakage of Thread Tools.—Sometimes the point of the thread tool will be chipped off from the right side, as shown in Fig. 27. This kind of break is usually caused by the slipping of the dog. The breaking strain was toward the right in the direction of the arrow. When the tool takes a heavy cut and the dog slips, the work will stop revolving while the lathe and feed continue. When the feed continues

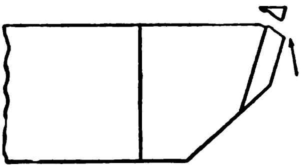


Fig. 28

and the tool point is in the thread, the tool must either slip or break. Sometimes a tool will break by chipping off the top face, as indicated in Fig. 28. Such a break indicates that the lathe was reversed and the work was running backwards before the tool was withdrawn from the cut. If the thread tool is too hard, the point will crumble; if too heavy a cut is taken, the point will be either broken downwards or burned off.

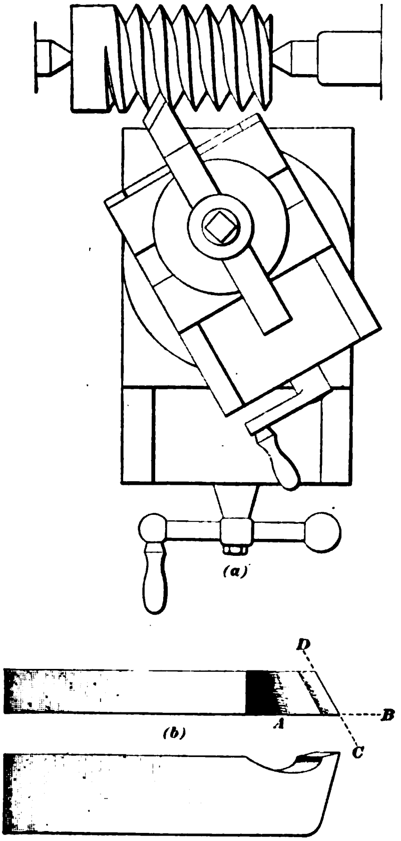


Fig. 29

59. Correct Height of Thread Tool.—The point or top face of the thread tool should be set level with the center of the work, or so that a line drawn from that point through the point of the tool will lie flat with the top face of the tool and square with the axis of the work. A thread of correct angle will thus be cut. If the thread tool is set too high or too low the threads will neither be cut deep enough nor have the correct angle and the sides will be curved instead of straight.

60. Top Rake of Threading Tools.—The ordinary threading tool that cuts with its two edges cannot be given any top rake or keenness. A thread may be cut with a tool having top rake by using the compound rest set at an angle of 60° with the center line of the work, as shown in Fig. 29 (*a*), and a tool shown in (*b*). The tool is ground so that the broad cutting edge *C D* makes an angle of 60° with the side of the tool, and the top face is given slope or top side rake. When the cut is taken, the tool is fed into the work by the compound rest. As the rest is set at an angle of 60°, it is evident that the blank side *A B* of the tool will just slide by the side of one thread while all the cutting is done with the keen edge *C D* of the tool.

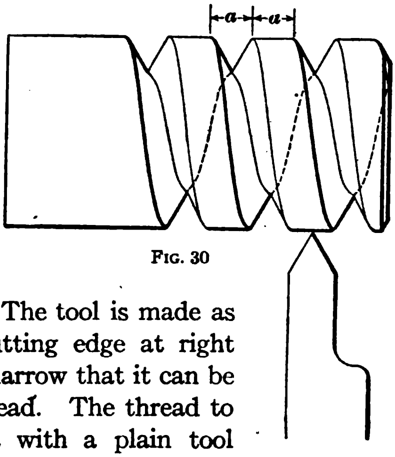


FIG. 30

61. A threading tool with top rake is often used, however, for cutting coarse threads on worms or hobs. The tool is made as in Fig. 30, but with the cutting edge at right angles to the shank, and so narrow that it can be fed to the bottom of the thread. The thread to be cut is first roughed out with a plain tool similar to the tool used for cutting a square thread. The compound rest is then set to the angle of the side of the thread, and the tool is fed down, first one side and then the other, until the space is of the right width. This method is frequently used when threads are too coarse to be cut with a single tool.

CUTTING MULTIPLE THREADS

62. Cutting Double Threads.—When a double or other multiple thread is to be cut, two or more threads must be cut in the space that ordinarily would be required for a single thread. A double **V** thread is cut by gearing the lathe to cut the lead of the double thread, which is twice the pitch of a single thread of the same height. Proceed as in cutting a single thread until the space left between the grooves is equal to the width of the grooves, as shown in Fig. 30. The work is then given half a turn so that the point of the tool will be opposite the center of the uncut part, as shown. The work may be given this half turn by removing and turning it so that the tail of the dog is in the notch of the face plate diametrically opposite the one used for the first thread.

63. If the face plate is not evenly slotted for multiple threading, another and better method for giving the half turn is to disconnect the feed-gears, and then turn the lathe spindle and the work half a turn. Suppose a change gear with forty-eight teeth is on the stud. One of its teeth that meshes with the idler, and also the tooth diametrically opposite it on the stud gear are marked with chalk, and the mark is carried onto the idler gear, after which the two gears are disconnected by dropping the idler yoke. The spindle and work are then turned so that the stud change gear passes over half its number of teeth, or twenty-four teeth. The work will have made half a revolution when the second mark on the stud gear coincides with the mark on the idler gear. The gears are then brought in mesh and the second thread cut the same as the first. If the lathe is compound-geared between the spindle and stud, instead of turning the stud gear half a turn, it is turned a proportional part, depending on the ratio of the compound. If, for example, the spindle makes two turns to one of the stud, the stud gear would make a quarter-turn.

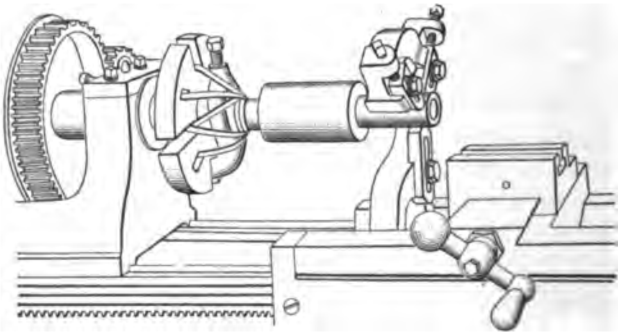


FIG. 31

64. Cutting Triple Threads.—After the first thread is cut, the space between the grooves should be double the width of the groove. The work is given a third of a revolution and the second thread cut, after which another third of a revolution is given and the third thread is cut. A similar method is used for cutting quadruple threads.

CUTTING INSIDE THREADS

65. Holding Work for Cutting Inside Thread. When an internal thread is to be cut in the lathe the work is held in a chuck or on a face plate, the same as for boring. If the work is long, one end is held in the chuck or on the live center, and the outer end is supported in a steady rest while the boring and threading are being done. If the work is held on the center, a *hold-back* is required. One form of hold-back is shown in Fig. 31, where a rawhide belt lace is used. The dog is clamped on the work as usual, and the work is placed on the center, after having unscrewed the face plate half way off. The lace is then used as shown, to lash the dog to the face plate, after which the ends of the lace are securely tied. The face plate is then screwed home, which draws the lace tight and the work into position.

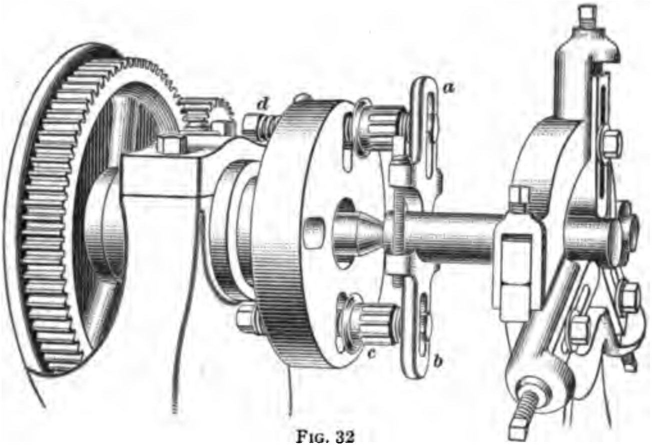
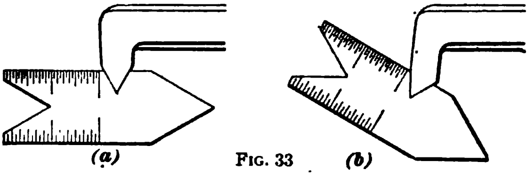


Fig. 32

66. A special hold-back dog is shown in Fig. 32. It consists of a clamp dog *a* secured to the work and has two slotted arms *b* through which studs *c* pass and enter slots or holes in the face plate. Nuts *d* on the other ends of studs are used to take up the slack and bring the work firmly against the live center.

A very good hold-back is made from a piece of hard wood 1 inch thick, of any required length and width. A large hole is bored central for the work to pass through and a hole near each end for each of two ½- or ⅝-inch bolts. The wooden hold-back is slipped on the work and the dog fastened as in Fig. 31. The hold-back is then brought up against the dog and the bolts are passed through it and the face plate, as in Fig. 32. Enough tension is put on the bolts to hold the work back against the live center without springing.

67. Tools for Cutting Inside Threads.—Inside-thread tools are similar to boring tools, except that the point is ground to the shape necessary to cut the desired thread. In grinding an inside-thread tool for a **V** or a United States standard thread, the point is ground to fit the gauge when the back of the gauge is nearly parallel to the shank of the tool, as in Fig. 33 (*a*). If the tool fitted the gauge when held in the position shown in (*b*), it would not go far into the hole before the back of the tool would touch the back of the hole.


(*a*) Fig. 33 (*b*)

68. Setting Inside-Thread Tool.—The inside-thread tool is set by placing one of the long parallel edges of the center gauge against the face side of the work so that the pointed end faces the thread tool clamped loosely in the tool post. The inside-thread tool is then set so that an edge of the tool is even with the angular edge of the gauge. It may also be set by placing the legs of the center gauge against the true faced surface, and setting the tool to the small notch in the side of the gauge. Fig. 34 (*a*) and (*b*) shows methods of holding the gauge against the work in order to set the tool true. Fig. 35 shows the result of bad grinding, which necessitates setting the shank of the tool at an angle with the axis of the hole, and it also shows how the tool may be pushed so far away from its cut at the front, when running the lathe backwards, that the tool will drag in the hole and spoil the first threads.

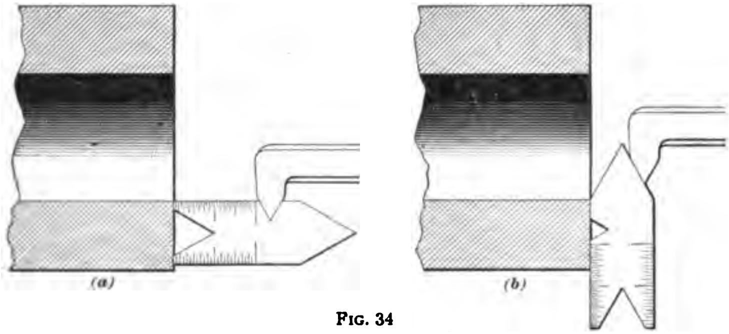


FIG. 34

69. Operation of Cutting Inside Threads.—When the inside thread tool is correctly set and the change gears are in place, the point of the tool is brought up to the surface of the hole next to the workman, and a light cut is traced through the hole. The stop or dial is set, and the tool is moved out of the cut and backed out of the hole by reversing the lathe. If possible, a gauge is tried on the traced thread to make certain that the gearing is correct. Repeated deeper cuts are taken in the same manner until the thread is deep enough. Lighter cuts are necessary when cutting an inside thread than when cutting an outside thread, owing to the greater spring of the inside-thread tool. The spring is very objectionable, as it results in chattering, so that the threads will usually be rough and tapered small at the inner end. If possible, it is best to finish the internally threaded hole by a tap guided by a center in the dead spindle.

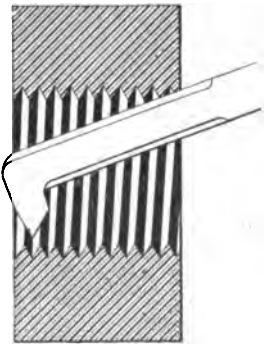


FIG. 35

The tap is well oiled and run carefully through the chased hole, while a wrench is kept on the shank to prevent it from turning with the work.

TESTING INSIDE THREADS

70. Moving Inside-Thread Tool From Work.—Most work that is threaded on the inside cannot be taken from the lathe and must be tested in place. The tool can be moved out of the way by reversing the lathe and allowing the carriage to feed back far enough to permit the gauge to be used; but this is a very slow way and is seldom employed. Sometimes it is possible to move the tool a sufficient distance to one side, by means of the cross-slide, to allow the gauge to be tried. If the tool is brought back to the stop after the work has been tested, it will be in place to continue the work.

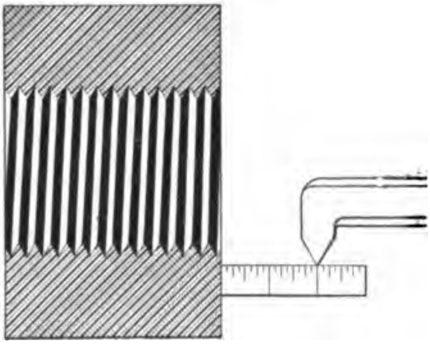


FIG. 36

71. Another method is to open the feed-nut in the apron, and move the carriage by hand out of the way. When this is done, some means must be provided whereby the carriage can be brought back to the same place and the feed-nut locked as before. To do this, the carriage is run back so that the tool is an inch or more out of the hole and then run forwards enough to take up the backlash. A chalk mark is then placed on the **V**'s at the headstock end of the carriage, and the position of the driving cone is noted or marked. A better method is to measure from the point of the tool to the work, as shown in Fig. 36. The split nut is then opened and the carriage is run back by hand. After testing, the tool can be moved back so that the measurement is the same as before and the feed-nut thrown in. Care should be taken that the spindle is not turned while the feed-nut is open, for it will cause trouble in getting the tool to start again in the correct place.

72. If the pitch of screw to be cut is a multiple of the pitch of the lead screw, this care is not necessary, for the tool will come correctly into the cut whenever the feed-nut is closed on the lead screw. When cutting these screws of multiple pitches of the lead screw, it is possible to keep the lathe running forwards all the time by throwing out the feed and moving the tool and carriage by hand back to the starting point. This operation will save much time.

73. **Testing Inside Threads With Gauge.**—After the thread tool has been moved away from the work and the hole has been cleaned, the gauge should be screwed in, taking care to have it exactly in line with the hole. Care always should be taken to cut the first thread deeper, so that it is not thicker than the others, owing to the spring of the tool at the beginning of the cut. When a tap is used in place of a gauge, the tap is sometimes made to take a very light cut from the hole, especially when square threads are being cut. When the tap is used for taking a light cut, to finish the thread, the tool is usually moved over by means of the cross-feed, and the dead center is introduced in the center in the shank of the tap, to guide it while it is being run through the work. Sometimes, when the piece is in a rather light chuck, the latter may be removed from the spindle and the work tried on the piece that it is to fit. This is very often done when the thread being cut is inside a new face plate or chuck back, the work being tried on the spindle of the lathe that it is intended to fit while it is still held in the chuck.

THREADING TAPERED WORK

74. **Setting Tool for Threading Tapered Work.** Threads on tapers are cut by two methods, one of which is to use the taper attachment, and the other is to set the dead

center over. In the first method, the tool is set by placing the center gauge against the cylindrical part of the work so

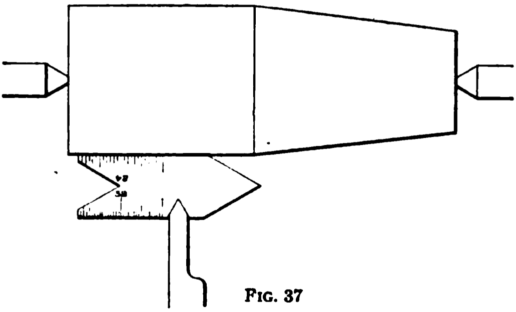


FIG. 37

that its back is parallel to the axis and adjusting the tool to the notch in the front of the gauge, as shown in Fig. 37. The gauge could be used in like manner against the dead spindle. The centers, of course, are in line and the sides of the thread will make equal angles with the axis. If the dead center is set over to turn and thread a taper, the thread tool is set by placing the back of the center gauge against the parallel part of the work after the center is set over, and adjusting the tool to fit the notch in the front of the gauge,

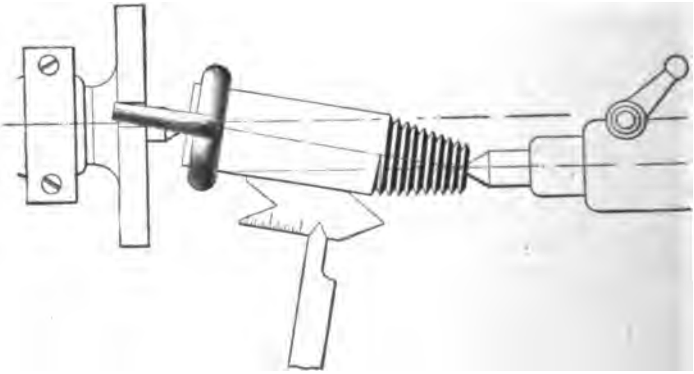


FIG. 38

as shown in Fig. 38. This setting is necessary to bring the sides of the threads to equal angles with the axis of the taper.

75. Cutting Threads on Tapers.—The taper attachment should be used when cutting taper threads, because a *true* taper thread cannot be cut by setting over the center. If the point of a thread is followed around a screw, it will be found to follow in the line of a true helix. If a thread should be so cut that, in following this curve, it would advance rapidly along the screw for a part of a turn, and slowly for another part of the turn, as when the center is set over, the rate of advance not being uniform, then the thread would not be a true thread, but would be known as a *drunken thread*. The set-over would also result in a shorter pitch of the thread.

ERRORS IN SCREW CUTTING

76. Errors Due to Imperfect Lead Screws.—The chances for error in screws cut in the lathe are numerous. The chief error is the inaccuracy of pitch due to an imperfect lead screw. The best remedy for errors of this kind is to use a lead screw that is known to be perfect within a given limit. All the lathes in a shop should be tested, and all particular screw-cutting given to those having the most perfect lead screws. In cutting long screws, the work frequently becomes heated above the temperature of the lead screw. Consequently, the screw being cut will be short when cool. The remedy is to keep the work cool with plenty of oil or water.

77. Accuracy of Lead-Screw Pitch.—When screws of accurate pitch or lead are desired, or when screws are desired that will be true with the axis of the work, they can be cut with more certainty on the lathe than with dies. The accuracy of the screw cut will depend on the accuracy of the lead screw in the lathe used. For ordinary threads, the ordinary lead screw is sufficiently accurate. When greater accuracy is required for such work as making taps or dies, the making of precision screws for measuring instruments, or similar work, a lead screw that has been most carefully made and has been tested all along its length must be used.

PRECAUTIONS IN CUTTING THREADS

78. **Perfectly Fitted V Thread.**—A V thread is sharp at its point and at its root, as was shown in Fig. 1. If a 1-inch thread were being cut, the thread would be complete when the groove cut by the tool just formed the sharp point of the thread. It is difficult to know just when this point is reached; therefore, the work is taken from the lathe and tested with a gauge or in the piece it is to fit. Fig. 39 represents a section through a bolt and a nut, showing how accurately the faces of the threads should fit each other. In practice it is usually better to turn the part to be threaded $\frac{1}{64}$ inch under size to be sure that the points of the thread will not bear in the threaded hole, thereby causing the workman to think that the sides of the thread are too full, and thus leading him to cut too deep and make a loose fit.

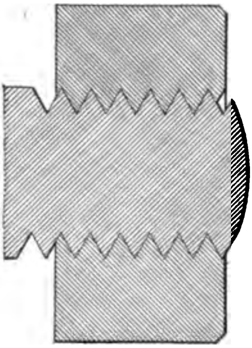


FIG. 39

79. **Calipering Threads.**—Before the final testing in the gauge or work, the thread may be tried by the use of thread calipers. These calipers are made very thin on their points, so that they fit into the V's of the thread and measure the diameter at the root, as shown in Fig. 40. They may be set either from a tap or from a standard gauge. A micrometer with a removable anvil may be arranged to caliper threads by fitting a piece of drill rod or wire in the anvil opening

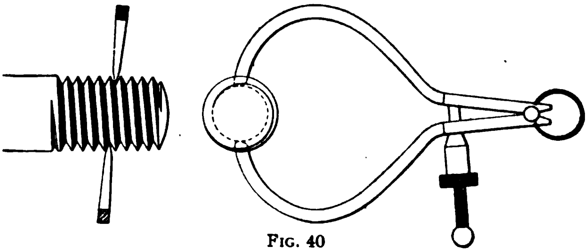


FIG. 40

opposite the spindle, as shown in Fig. 41. A V corresponding to a certain pitch of thread is cut central in this piece, and a mating point is fitted to the measuring spindle and held in position by a setscrew. The point is ground to 60° for V threads and other points can be made flattened for various pitches of United States standard threads. This micrometer attachment will not measure the exact diameter, but will measure the variation in size of a thread or of two or more similar threads.

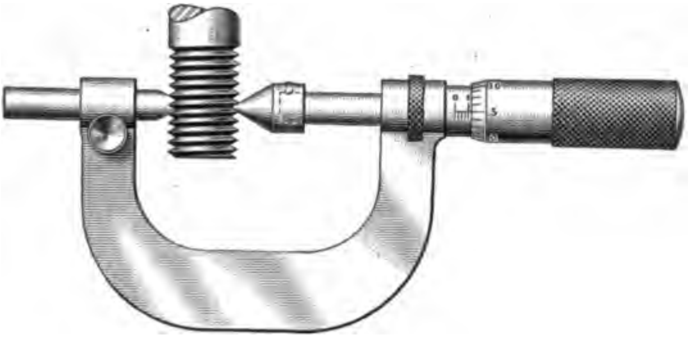


FIG. 41

80. Effect of Using Dull Thread Tools.—A bolt threaded with a dull-pointed tool is shown in Fig. 42. The threads are rounded at the bottom because of the rounded point of the tool. When this kind of thread is tried in a perfectly threaded nut, as shown, it will not enter until the thread is cut sufficiently deep to allow its rounded root to pass in. This may so hold the work that no lost motion can be detected at first; but the piece will soon wear loose, as there is no bearing on the sides of the threads as there should be.

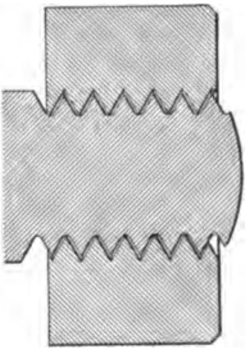


FIG. 42

81. Effect of Using Dull Taps. In the case shown in Fig. 43, the nut to be fitted has been tapped with a dull tap, which left the threads slightly rounded in the bottom. When a sharp-threaded screw of full diameter is tried in such a nut, it will not enter. By cutting the screw smaller, it will go in; but the fit will be as shown, the bearing being entirely on the points of the threads. In practice, when the thread has been cut to a sharp point and will not enter, this trouble should be looked for, and if the threads in the nut are found imperfect, the points of the screw being cut should be slightly rounded with a file. A screw thread should always fit by bearing on the sides of the threads and never on the points.

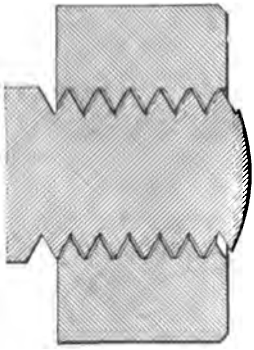


FIG. 43

82. Advantage of Large Tap Holes.—In machine construction where holes are drilled and tapped for **V** threads in various parts of castings, it is customary to drill the holes slightly larger than would be necessary to cut such a full sharp thread as shown in Fig. 39. After the holes are tapped, they are more nearly of the shape shown somewhat exaggerated in section in Fig. 44, where it may be seen that the threads are not full on the points. When a bolt is being fitted to this kind of tapped hole, the necessity of keeping a very sharp point on the tool and cutting the thread sharp at the root is not so important.

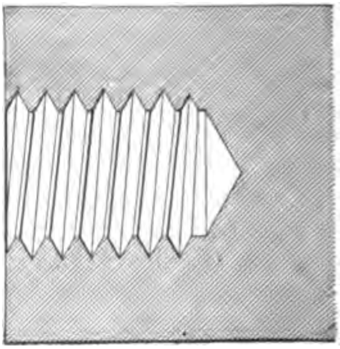


FIG. 44

83. Effect of Slight Difference of Pitch on Fit.—A section through a bolt and a nut having slightly different pitches is shown in Fig. 45. In fitting such a bolt, it will be found on trial that it enters the nut for a few turns easily, growing tighter as it is screwed in, with the appearance of being tapered. After more cutting, the bolt will pass through the nut, appearing to fit. When the end of the bolt is once passed through the nut, it will not fit any more closely as the nut is screwed along the bolt. When a bolt and a nut are of slightly different pitches, the effect is much more noticeable if the nut is long than if the nut is short. The real contact may be seen from Fig. 45. In this case, the thread on the bolt is of a coarser pitch than the thread on the nut, and bears only on the first and last threads of the nut.

84. Fitting Threads on Same Lathe.—When two threads are to be cut that must fit each other perfectly, the internal thread being long, it is desirable that they be cut on the same lathe. By its use they can be made to have the same pitch, and if there is any error in the pitch, it will be the same in both threads.

85. Replacing Work in Lathe. If, after testing in the nut, the screw is found to be too large, it should be replaced in the lathe and a sufficient number of light cuts taken to reduce it to the desired size. The notch in the face plate used for the tail of the dog must be noticed and marked, and the dog put back in the position from which it was taken. Failure to do this will cause the point of the tool to start another thread that will destroy the one nearly completed.

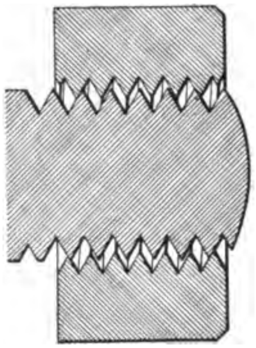


FIG. 45

86. Resetting Threading Tool.—When the threading tool has been removed, it may be reset as follows: Adjust the tool in the tool post to fit the gauge, Fig. 10, the same as before the thread was started. Turn the spindle forwards and note if the tool point comes opposite the cut in the work. If not, drop the intermediate gear *c*, Fig. 23, away from the gear *b* on the spindle. Turn the spindle forwards until the tool comes exactly opposite the notch in the work. Bring the tumbler gear in mesh with the spindle gear, which will throw in the feed, and proceed to cut the thread as before. The lathe must always be turned forwards, so as to take up the slack or backlash in the gears and the lead screw. The backlash can be noted at the time the lathe is reversed, when it will be seen that the work may make a part of a turn before the tool will start to feed back. The tool will then drag behind, and if brought up to the work when it is running backwards, the tool would not fit in the notch as it did when the lathe was running forwards. If the lathe has a compound rest it should be set around about 30° before setting the thread tool square with the axis of the work. If the thread tool does not enter the thread cut in the work as the work turns for cutting, the tool can be advanced sidewise by use of the compound rest, so that it fits perfectly in the cut already made.

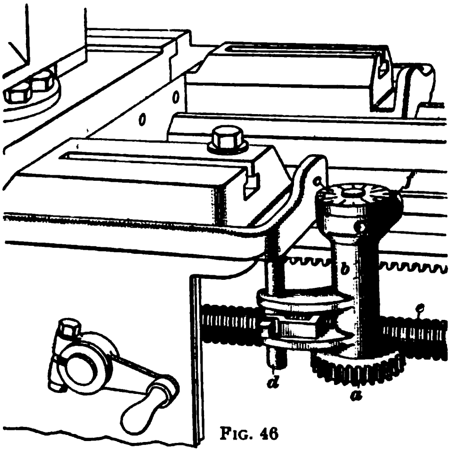


FIG. 46

87. Opening Lead-Screw Nut.—If short threads are being cut, it is usually best to leave the split nut closed and run the tool back to the starting point for each new cut. The thread is cut by running the lathe backwards and forwards the required number of times to cut to the required depth. If the screws to be cut are long, the split nut should be opened and the carriage returned by hand. If the pitch of the thread being cut is a multiple of the lead-screw pitch, the nut may be opened, and after returning the carriage to the starting point it may be closed anywhere and the tool will be in position to start in the cut. If the pitch of the thread is not a multiple of the pitch of the lead screw, a mark is made on the lathe bed at the point where the carriage starts and another mark is placed on the large spindle gear, with a corresponding mark on the headstock casting at the position occupied by the spindle when the cut ends. The lathe is run forwards when cutting until the end of the cut is reached.

It is then stopped with the mark on the spindle gear opposite the mark on the headstock casting. The nut is then opened, the carriage is run back to the mark on the bed and the split nut is closed. This method can be used to advantage if the lathe has no backing belt.

88. Thread Indicator.—An attachment put on many lathes to show when to throw in the split nut on the lead screw while cutting is called the thread indicator and is shown in Fig. 46. It consists of a worm-wheel *a* connected to a short, vertical shaft that turns in the bracket *b* and carries a dial *c* at the upper end. The bracket is swiveled on the pin *d*, so that the indicator may be swung away from the lead screw *e* when it is not in use; or it may be removed entirely. A pointer *f* is formed on the upper end of the bracket and the split nut is thrown in when the proper graduation comes opposite this pointer.

89. Lubrication for Thread Cutting.—When cutting screws in a lathe, lard oil should be freely applied to the tool and the work. The finishing cuts should be light shaving cuts. The tool should be ground sharp and finished with an oilstone. The oil is usually applied to short threads by placing a pan of oil under the work and putting the oil on with an oil brush. If the screws are long, an oil pan is placed under the work and a drip can is so arranged that a supply of oil will follow the work above the tool.

RIVETT THREADING TOOL

90. A threading tool, by means of which many of the difficulties in screw cutting may be overcome, is shown in Fig. 47. It consists of a cutter *a*, resembling a milling cutter, supported on a bracket *b* by a slide *c*. The device is clamped on the tool rest of a lathe from which the tool post has previously been removed. The cutter *a* has ten teeth on its circumference, each one formed to cut deeper than the preceding one, and gives the thread its actual width to the full depth of the cut. For instance, in Fig. 48, the first tooth cuts the full width of the thread to the line *1*, the second cuts to the line *2*, and so on until the tenth tooth cuts to the bottom.

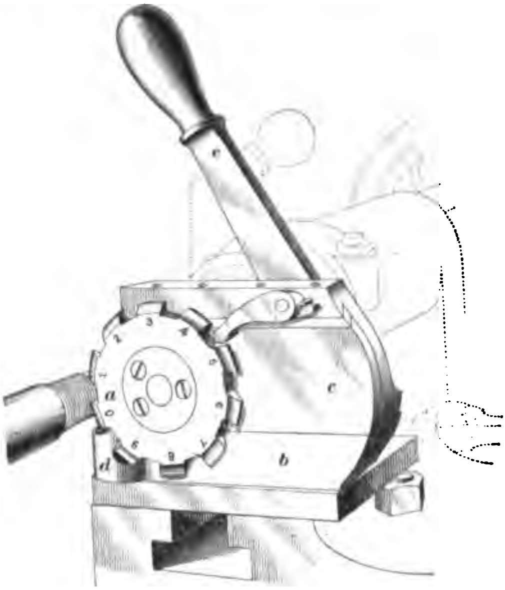


Fig. 47

In Fig. 49, the views (*a*), (*b*), (*c*), (*d*), (*e*), and (*f*) show the shapes of the teeth and the corresponding forms of the thread for the first, second, third, fifth, eighth, and tenth cuts, two and one-half times the actual size of a 7-pitch **V** thread.

91. The tool is set up and adjusted for the first cut, as shown in Fig. 47, proper side rake for either right-hand or left-hand thread being given by means of an adjusting screw on the far side of the device, which is not shown. The tooth rests on the support *d*, which holds the top face level with the center line of the screw. When all adjustments have been made, both the device and the rest are clamped, and the first cut is taken. The rest is then brought back to its starting point in the usual way. The second tooth is brought into position and

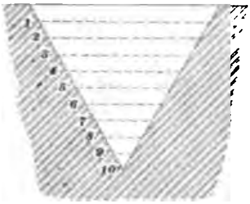


Fig. 48

locked by throwing over the lever *e* and bringing it back into place. The second cut is then taken and the operation is repeated until the tenth tooth has taken its cut. The last tooth may be advanced in nine steps by means of an eccentric stud and micrometer stop. Each step advances the cutter a fraction of a thousandth of an inch, thus permitting very fine fits and exact duplicates to be made.

92. The special advantage claimed for this tool is that each tooth comes to the work in better condition than when a single tool is used, the work being distributed over ten cutting edges instead of one. The finishing tool comes into service with a sharp point, and its duty is comparatively light. Under these conditions, the lathe can be run at a higher speed, as the danger of injuring the tool point by its continuous use on every cut has been eliminated. A perfect thread can, therefore, be formed in less time without injury to the tool. For rough work many shops prefer the ordinary single tool, the thread being finished with six or seven cuts.

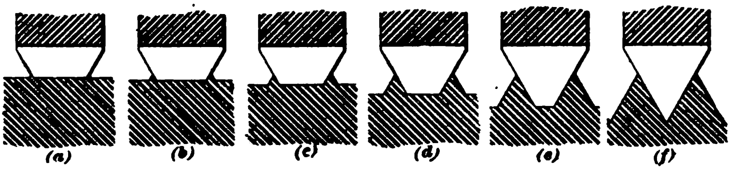


FIG. 49

GEAR-BOX METHOD OF GEARING LATHE FOR SCREW CUTTING

93. Construction of Gear-Box.—The operation of changing the gears for every desired pitch of screw takes considerable time and affords opportunity to make mistakes. The gear-box system avoids these objections and is applied to small and medium-sized lathes. A lathe so geared is shown in Fig. 50. All the change gears are on a shaft in the gear-box seen at the front of the lathe, directly under the headstock. To change from one set of gearing to another, the knob *a*, which moves in the slot in the gear-box, is moved to a position indicated by the table or index plate above the gear-box.

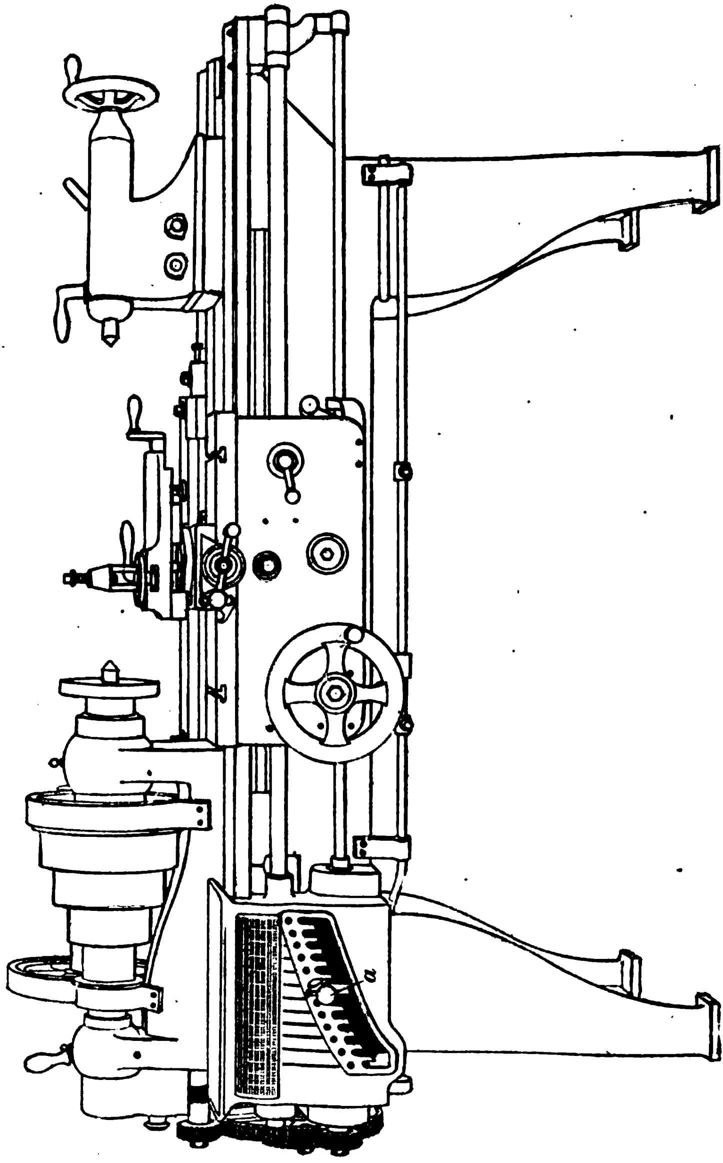


Fig. 50

The back of the gear-box is shown in Fig. 51 with the lead screw *a* projecting from the left-hand side. Twelve gears *b* are keyed on the lead screw inside the gear-case. A sliding gear *c* and an idler *d* carried on a yoke can be moved to engage with any one of the gears in the lead-screw cone, giving twelve different speeds to the lead screw. At the right of the gear-box is the compounding box *e* containing gears that give three different speed changes to the shaft and the sliding gear *c* and when combined with the twelve gears on the lead screw give thirty-six speeds or threads that can be cut.

94. Index Plate.—Above the gear-box is an index plate giving various data in relation to the use of the gear-box. The conditions vary with each different make of lathe, so each different plate must be studied to acquire all the information there given. The two conditions most commonly stated are the number of threads per inch to be cut and the position of the sliding gear. This information is applied by taking the number of threads per inch to be cut as the starting point. The pin attached to the sliding gear is put in the notch or position specified and the yoke is then moved to the proper gear on the gear cone, which makes the lathe ready for use. If the feed for plain turning is governed from the gear-box, this fact is also stated on the plate as a certain

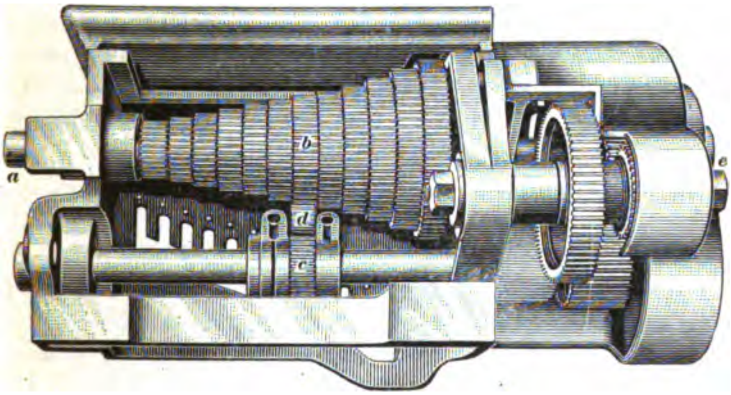


FIG. 51

number of times the number of threads per inch cut; thus, if the feed is stated as six times the threads per inch, it means that the movement of the carriage is six times as rapid as for cutting the thread for which the gear-box is set.

CUTTING THREADS BY HAND

95. Methods Used for Cutting Threads.—When accuracy of pitch is desired, or the screws are long, the thread should be cut in a lathe, between the centers. If a limited number of short threads is required, they can be advantageously cut by hand with dies; if a large number is required, they can be produced by means of a special bolt-cutting machine with a die that cuts the thread to size at one passage over the work.

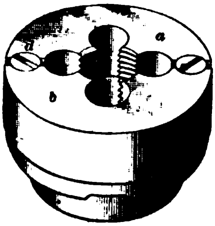


FIG. 52

96. Hand Dies.—A thread-cutting die that is intended to be operated by hand is shown in Fig. 52. It is held in a die stock, as shown in Fig. 53. When these hand dies are used, the rod to be threaded is held in a vise. The die is then well oiled and screwed down on the end of the rod until the desired length of screw has been cut. Some pressure will be necessary to start the die; but after a few threads are cut it will feed itself along as it is revolved. The die shown in Fig. 52 is adjustable within certain limits. Fig. 54 shows it with one half removed. The parts *a* and *b* compose the cutting die proper. The part *c* is a guide that slips on the end of the work and holds the die true when starting the thread. Adjustment is made by the tapered-head screw *d*. When screwed into the lower guide, it forces the halves of the die apart slightly, thus causing them to cut a larger thread. When

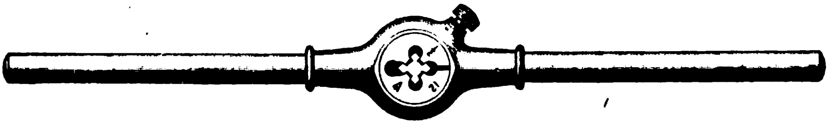


FIG. 53

in use, the two halves of the die are kept from springing apart by being held in the die stock.

97. Inaccuracy of Pitch.—Hand threading is slow, as it requires nearly as much time to remove the die from the work as to cut the thread. Hand-cut threads can never be depended on to be true with the axis of the work, as the guide does not fit with sufficient accuracy to start the die perfectly true. Worst of all is the inaccuracy of pitch. It is not uncommon to find dies that would cut a thread which, if continued for a foot in length, would be in error $\frac{1}{8}$ inch. With care, dies can be made that will cut short threads with sufficient accuracy of pitch for ordinary commercial purposes.

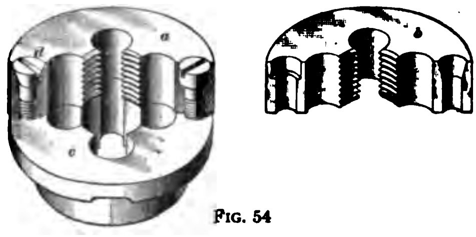


FIG. 54

BOLT CUTTERS

98. General Description.—For rapid screw cutting, special machines are used, called bolt cutters, that rotate the dies while the work is held in a chuck. Fig. 55 shows a type of double-head bolt cutter, so called because it carries two heads or die stocks. The work is clamped horizontally in the machine in the jaws or chucks *d* by means of the large hand pilot wheels *a*. The chuck and the work are moved up to the dies *c* by means of hand wheels *b*, these wheels operating gears that engage with the racks shown.

99. Automatic Dies.—The dies used on bolt-cutting machines are quite different from the hand dies just described. They are automatic in action, so that when the die has cut a sufficient length of thread on the bolt, a lever automatically opens the die, causing it to cease cutting and allowing the work to be withdrawn freely, thus saving much time. Fig. 56 shows one style of head for bolt cutters designed to hold detachable dies. Dies of various sizes may be used in this head for cutting different diameters of bolts. Fig. 57 shows the principle of this style of automatic head. The body of the head *b* has four radial grooves cut in the end, in which the four dies *d* can slide. A cap *c*, fastened to the head *b* with screws, holds the dies in place. The outer ends of the dies are beveled, as shown, to form cutting edges for removing the scale and any metal that may be in excess of the thread diameter. The thread is then cut by the toothed parts of the dies at one passage over the stock. The ring *r* fits over the head *b* and partly over the ends of the dies. When in the position shown in the illustration, the dies are open. To close them, the ring *r* is pushed in the direction of the arrow, over the ends of the dies to the position of the dotted lines. Each of the dies is thus forced toward the center. When in this position, the dies are ready to cut. Levers are so arranged that after a thread of the desired length is cut on

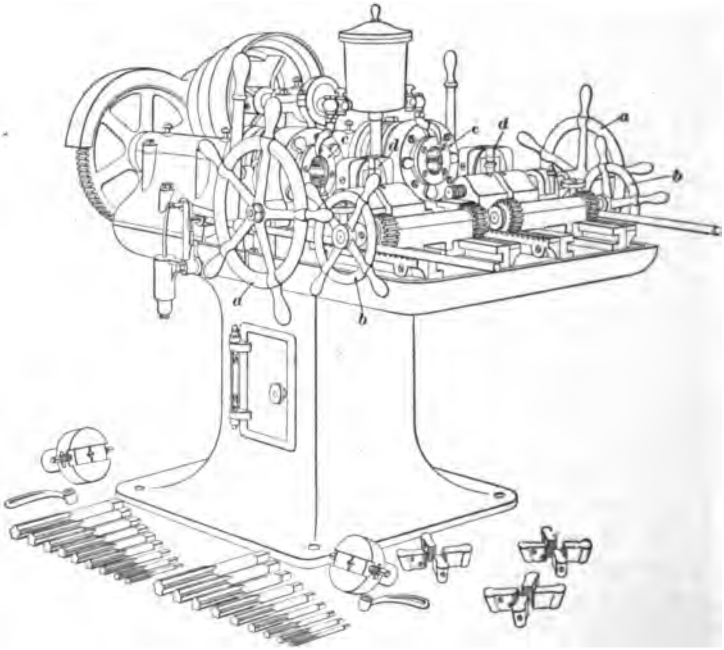


Fig. 55

a bolt, the ring *r* is suddenly released and moved back to its normal position, as shown. This action releases the dies, which are as quickly opened by the cylindrical portions *a*, Fig. 56, sliding in the ring *r*, and the dies cease to cut. The threaded bolt is removed and another substituted. The diameter of the thread being cut can be varied to make either a tight-fitting or a loose-fitting screw by increasing or decreasing the travel of the ring *r* on the inclined ends or caps of the dies.

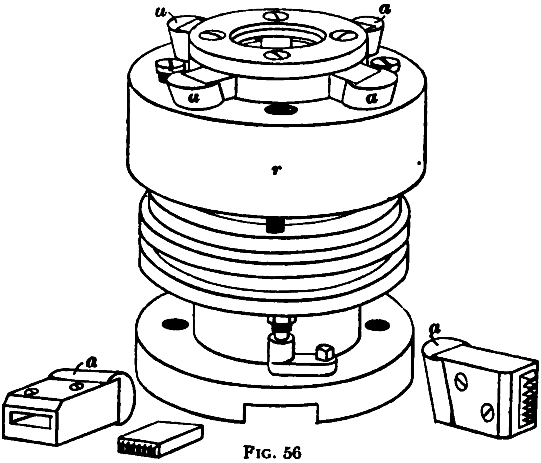


FIG. 56

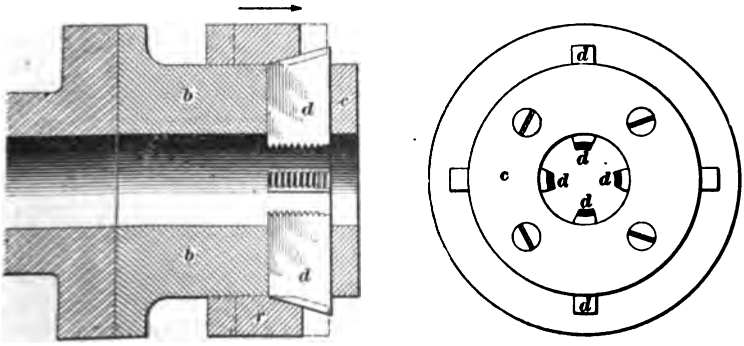


FIG. 57

100. Bolt Cutters with Lead Screws.—When used for ordinary bolts with short threads, bolt cutters usually have the bolt clamped in the carriage chuck by which it is moved up to the die and fed in by a hand-operated pilot wheel and gear working in a rack on the bed. After the die has taken hold, the bolt will feed in by the pull of the thread in the die. If longer or more accurate screws are required, or special forms like the square and Acme thread are to be cut with a die, the bolt cutter is provided with a lead screw to feed the carriage and stock along to the die at the required rate. The lead screw is held in a socket under the head and is driven by suitable gearing. A split nut in the carriage can be closed on the lead screw so that the carriage is given a movement as accurate as the carriage of a lathe. A very accurate screw may be cut by this process.

When bolt cutters and tappers are being used, a stream of lard oil is kept flowing on the dies, taps, and work, to keep them cool and to lubricate the cutting edges.

TAPPING

101. Use of Taps.—The operation of cutting internal threads is similar to that of cutting external threads, when done on the engine lathe. Internal threads are usually cut by the use of *taps*, which may be operated by either hand or machine power. The use of taps for cutting internal threads is the common practice, and only when large or special forms of threads are desired is the lathe employed.

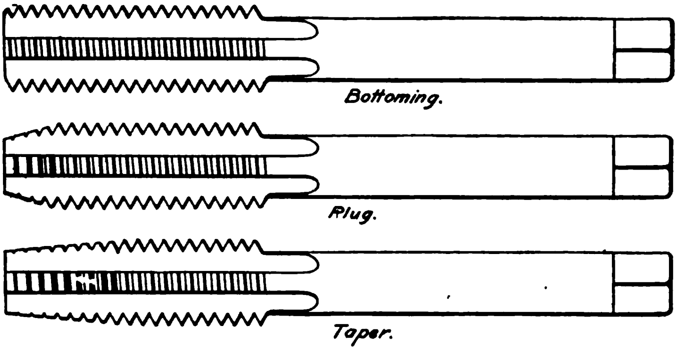


FIG. 58

102. **Hand Taps.**—Small taps are made from a solid bar of steel, accurately threaded and fluted, hardened, and then tempered. Fig. 58 shows a set of machinists' hand taps. A set consists of a *taper*, a *plug*, and a *bottoming tap*. Large taps may be made from the solid, but are oftener made as shell taps and used on suitable shanks; they are also made as inserted-blade taps.

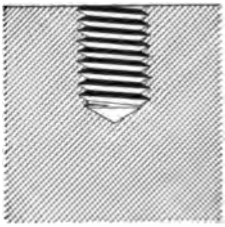


FIG. 59

103. **Tapping Holes.**—When a hole has been drilled entirely through a piece, it is necessary to use only the taper tap, which may be run entirely through the piece being tapped. When a hole that has been drilled partly through a piece is to be threaded to the bottom, as shown in Fig. 59, it is necessary to use all three taps. The taper tap is needed to start the thread, and is screwed in until it touches the bottom of the hole. The plug tap is next employed, which, when screwed to the bottom of the hole, will cut full threads somewhat deeper; and for finishing the bottoming tap is used.

104. **Attachments for Tapping.**—There are a number of tapping attachments to reduce the labor of tapping holes. Some of these require the reversal of the spindle of the machine and others are reversible. In either class of attachment the plug tap is generally used when tapping cast iron and run to the required depth and backed out. Taps should be oiled with lard oil before being started into holes.

105. **Machine Tapping.**—The taper tap is used for machine tapping, the principal difference being that it has a longer shank than the hand taper tap. The tapered part of the machine tap or nut tap is so threaded that it will more easily start in the hole. Nut taps are made with long shanks,

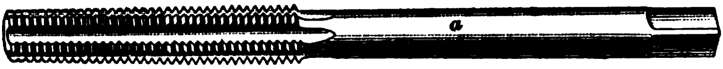


FIG. 60

as shown in Fig. 60, so that a number of nuts may be tapped by running the threaded part of the tap through them and allowing a number to remain on the plain shank *a* until it is full, when the tap is removed from the holder, the tapped nuts slid off, and the tap replaced. The machines used are similar to those employed for bolt cutting. The die head is removed and the taps are held in suitable chucks in place of the die heads. Vertical machines are also largely used for tapping and often are of the multispindle type.

LATHE WORK

(PART 6)

TYPES OF LATHES

TURRET LATHE

1. Characteristic Feature of Turret Lathe.—Probably no one machine deserves greater credit for advancing the movement toward rapid production, and, consequently, the reduction of cost of manufactured articles, than the turret lathe. Its special mechanical feature is the turret, which is used to bring, in quick succession, a number and variety of cutting tools to act on a bar or rod passed through the hollow spindle in the headstock and held in a chuck.

2. Action of Turret.—The turret is a solid revolving block or tool holder either round or having flat sides, in which a number of holes are drilled, bored, and reamed by tools held in the spindle so that each one of them can be brought in line with the spindle axis by revolving the turret. A tool capable of performing one or more operations on the work is held in each hole of the turret. The turret may also be made in the form of a rigid flat, slotted table to which open tool holders may be secured. Hollow or box turrets are also used to some extent.

3. The turret is mounted on a slide, parallel to the line of the live spindle, and occupies a position relatively the same as the tailstock on the ordinary lathe. It is made to slide on the base either automatically or by a hand lever or wheel. After

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the tool, which is held in one of the radial holes in the turret, has made a certain cut on the work, the turret is moved back, and is automatically unclamped and rotated a part of a turn on a vertical axis. The second tool in the turret is thus brought in line with the work. Each full backward movement of the turret revolves it a part of a turn, sufficient to bring the second tool in perfect line for the second cut. One or more stops are also provided, so that the tools will be fed the right distance on the work.

4. **Types of Turret Lathes.**—The turret has been applied to a variety of lathes for various kinds of work, so that there are, under the head of turret lathes, the turret screw machine, the plain turret lathe, the brass-worker's lathe, the flat turret lathe, and the monitor lathe. There are also other special forms of turret lathes that are adapted to certain classes of work. The screw-machine class includes hand and automatic machines.

HAND SCREW MACHINE

5. **Features.**—The hand screw machine has more of the features of turret lathes than any other type. Fig. 1 represents a typical turret screw machine. Its special features are the turret moving on a slide that takes the place of the tailstock, a special form of chuck for gripping rods, and the rod-feed mechanism for feeding the work into position. In the lathe shown in Fig. 1, the parts are named as indicated by the following letters: *a*, the turret; *b*, the pilot wheel for moving the turret; *c*, the stop-screw for adjusting the travel of the turret slide; *d*, a special chuck for holding the rod, or stock; *e*, the lever for opening and closing the chuck *d*, and for feeding the rod into the machine; *f*, supports for holding long rods; *g*, the front tool post; *h*, the back tool post; *j*, the cross-slide; *k*, the handle for operating the cross-slide; *l*, the distributing pipe for oil; *m*, the oil tank; *n*, the clutch for operating the chuck. In the larger sizes, the screw machine is provided with a feed-rod, like that of an engine lathe, which is used for feeding the tools to the work.

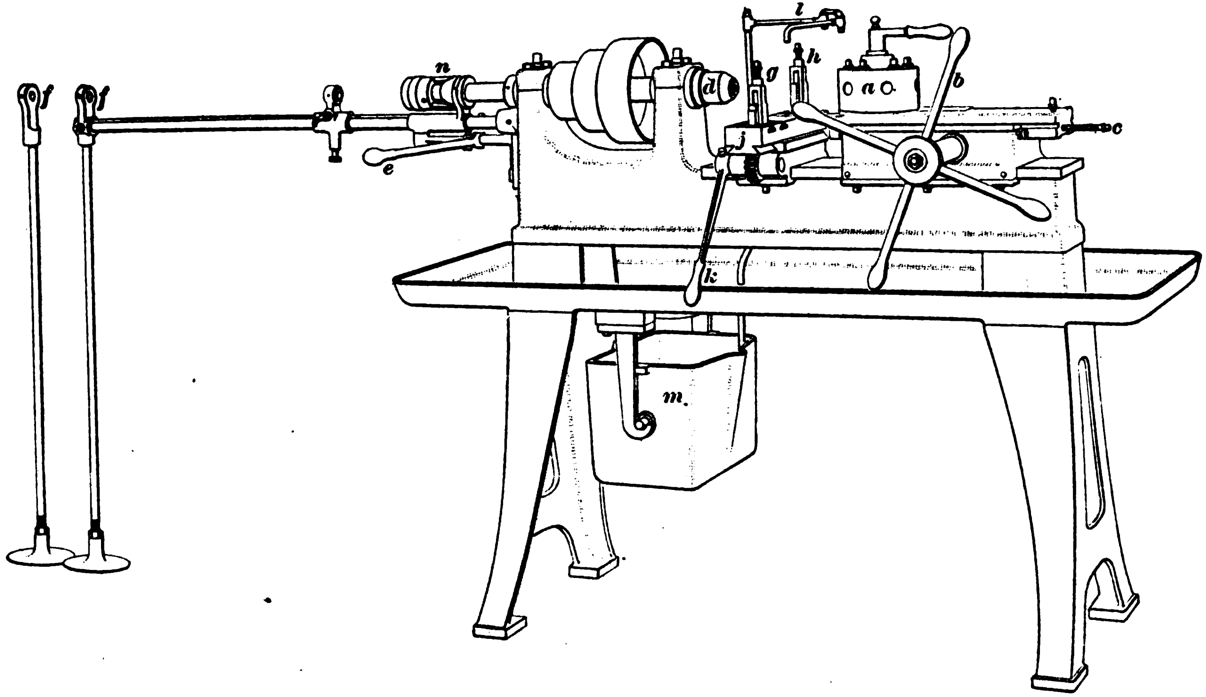


Fig. 1

6. Chuck.—The success of the screw machine is due largely to the method employed in holding the work; this method gives great rigidity, and at the same time is so simple that the work can be quickly clamped or released. In Fig. 2 is shown a section through the chuck screwed to the spindle of a lathe as it is used for holding rods. The grip of the rod is accomplished by pushing the split collet *a* through the tapered hole in the end of the cap *b*, the cap being screwed to the nose of the lathe spindle. Fig. 3 shows the collet *a* removed. The collets are made of various sizes, depending on the size of the rod to be held, and are hardened, as is also the cap in which they slide.

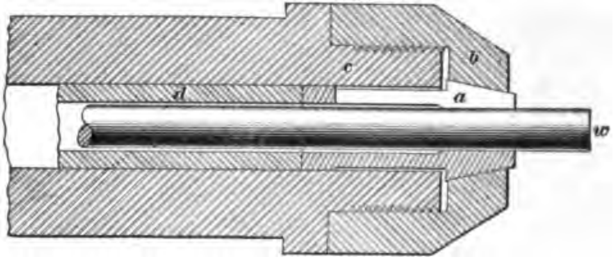


FIG. 2

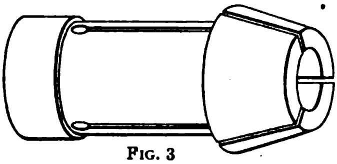


FIG. 3

7. When gripping the work, the collet is pushed into the cap *b*, Fig. 2, by means of the hollow tube *d*, which passes through the lathe spindle to the rear end. Fig. 4 shows a section through the rear end of the spindle and the gripping

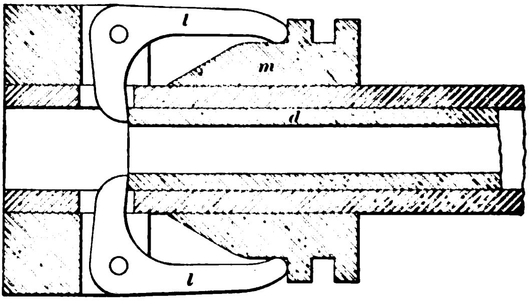


FIG. 4

mechanism. The end of the tube *d* comes against the two levers *l*. These levers are operated by the cone-shaped piece *m*, which slides on the spindle. When the cone *m* is moved to the position indicated, the ends of the levers are forced apart, which moves their other ends against the end of the tube *d*. This operation pushes the tube through the spindle and against the collet, thus causing it to grip the work. When the cone *m* is moved back, the long ends of the levers spring together and relieve the pressure on the end of the tube *d*. Springs are arranged to open the chuck as soon as the cone *m* is removed from under the levers *l*. In this description, only the essential points have been mentioned, all unnecessary details, such as springs, being omitted.

TURRET TOOLS AND THEIR USES

8. The work of the turret screw machine is confined to such work as can be made on the ends of rods held in the chuck. Turret lathes are, therefore, without centers for supporting the work. The tools used for the turret are quite different from those used in the engine lathe. The work of the screw machine can be understood by following the operations necessary to complete some particular piece. Suppose, for example, that it is necessary to make a large number of screws with round nurled heads, as shown in Fig. 5. Having decided on the form of screw to be made, the machine must be set up.

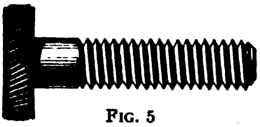


FIG. 5

9. The setting up of the turret screw machine includes setting the various tools in the turret and in the cross-slide, adjusting the stops to determine the lengths of cuts, and adjusting the cutter blades to turn the correct diameters. A rod is put through the spindle, and the chuck is so arranged that the work can be gripped rigidly, and also so that when it is released the feed will move the rod through the spindle.

10. Stop-Gauge.—The first tool used in the turret is the adjustable stop-gauge shown in Fig. 6, which determines the correct length of stock for the work. This stop is so adjusted that when the turret and slide are at the full length of their travel next the headstock, and the work is fed up to the stop and gripped in the chuck, the correct length to make the screw will project from the chuck. Having clamped the work, the turret is moved back and revolved a part of a turn, which brings the first turning tool to place.

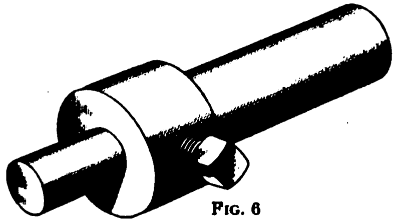


FIG. 6

11. **Roughing Box Tool.**—The first turning tool to be used in the turret is the roughing box tool, shown in Fig. 7. The shank *s* is held in the turret, and the tool, or blade, *c* is clamped in place by the screws *a*. The tool is adjusted to turn the correct diameter by a series of careful trials. To support the work while the cut is being taken, the back rest *r* opposite the tool *c* must be adjusted so that it just supports the end of the work. Fig. 8 shows an end view of the box tool with a section of work *w* in place. This view shows how the tool, or blade, *c* comes against the work, and how the back rest supports it.

12. Turret lathe tools do not need so much keenness as those on ordinary lathes. With the tool shown in Fig. 8, a cut is taken over the body of the screw up to the shoulder under the

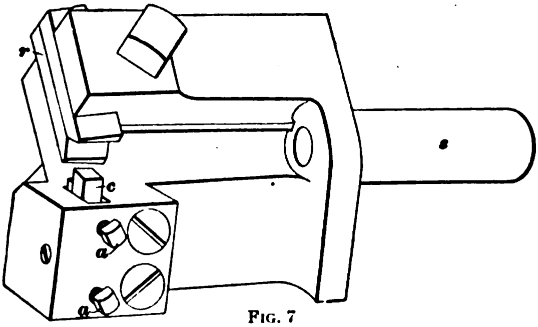


FIG. 7

head. If the bar is iron or steel, a supply of lard oil is kept running on the work, to prevent it and the tool blade from heating. When this roughing tool has cut a sufficient length, the turret slide comes against a stop. This stop is so adjusted that each tool will stop when the right length has been turned. The turret is given another partial turn, which brings the second cutting tool, or finishing box tool, in line for the cut.

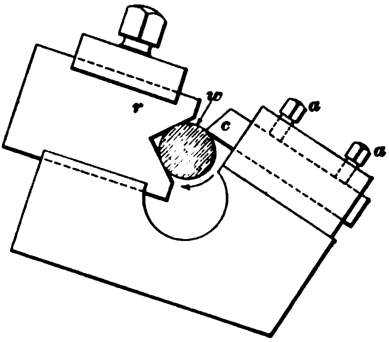


FIG. 8

13. Finishing Box Tool.—The same principle as the roughing box tool is used in the finishing box tool, except that the blades are made and adjusted to cut similarly to a broad-nosed lathe tool. The blade for the rough cut is ground on the same principle as the roughing tools for lathe work. As shown in Fig. 9, a finishing box tool has a number of cutters, each of which may be adjusted to cut to a given depth by the setscrews *a* at the ends of the blades. The blades are used when it is necessary to finish parts to different diameters at the same time. Each blade is so adjusted along the length of the box tool that

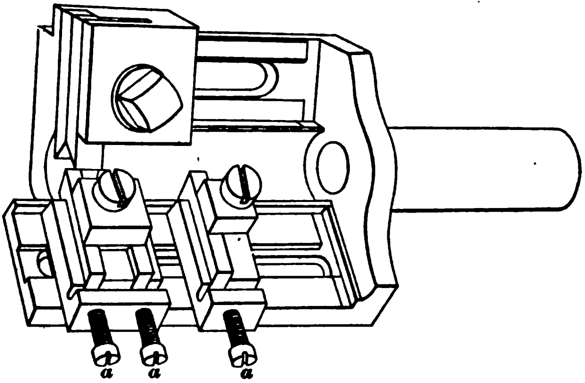


FIG. 9

it will turn the required length of work to that particular diameter. For the screw being made, only the first blade in the tool will be used. This blade will be adjusted to finish the body of the screw to the correct diameter.

14. **Pointing Tool.**—Before cutting the thread, the end of the body should be beveled or chamfered. This is done with a pointing tool, which is similar to the roughing box tool shown in Fig. 7. The blade, however, instead of being straight on the edge, is beveled to an angle, the same as the bevel on the end of the screw. The back rest is adjusted on a pointing tool the same as on other box tools. When fed against the end of the work, this tool will cut the required bevel.

15. **Dies and Die Holders.**—The screw is now ready to be threaded. The threads are cut with dies on all screw machines. In order that the thread will be cut an exact length on the body of each screw, a releasing die holder, as shown in Fig. 10, must be used. The die holder *a* has a circular opening in which the dies are fastened by the screws *e*. The stem *d* passes through a sleeve that has a flange on one end and that is held in one of the holes in the turret. When in the position shown in the illustration, the holder is free to revolve in the sleeve. When it is used and the die is fed against the work, the holder slips back in the sleeve until the pins *b* and *c* engage each other. The pin *c* will then keep the die holder from revolving. As soon as the holder ceases to revolve, the die will begin to cut, and after cutting a few threads it will feed itself along the work.

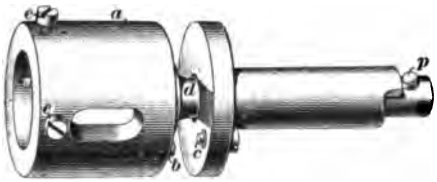


FIG. 10

16. If provision were not made to stop it as the work continued to revolve, the die would at once screw up to the shoulder on the work and destroy the thread. With the holder shown, the die will feed along the work, the turret being made to follow

it, until the turret slide reaches its stop. The work, however, continuing to revolve, will feed the die still farther, and bring the holder with it until the pins *b* and *c* disengage, whereupon the holder again revolves with the work, thus stopping the cut. In the meantime, the direction of the lathe is reversed and the turret moved back by hand until the backing pin *p* engages the notch cut in the end of the sleeve. The holder is thus kept from turning backwards, and so the die is backed off the screw. When considerable uniformity of size of threads is necessary, a second sizing die is run over the thread. These operations complete the turret operations on the screw.

CROSS-SLIDE TOOLS

17. Nurling Tool.—When the head of a screw is to be nurled, one or more hardened-steel rolls are fed against the face of the work while it revolves. These hardened-steel rolls have teeth, or a special design, engraved around their outside, so that, when rolled against the work, they will impress the design in the soft metal. In the case described, the nurling tool shown in Fig. 11 is employed and held in one of the tool posts on the cross-slide.

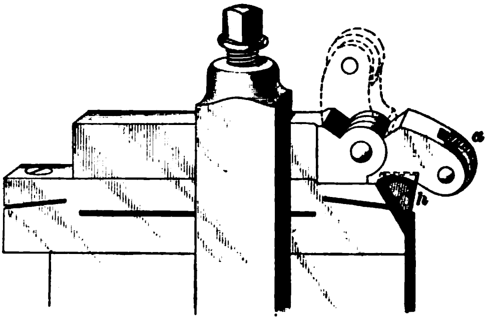


Fig. 11

18. Parting Tool.—The parting tools used in the turret lathe for plain cutting are similar to those used in a regular lathe, and are held in one of the tool posts on the cross-slide. Combination parting and forming tools are often employed. They are designed to round the head and cut off the stock at the same time.

19. Combination Parting and Nurling Tool.—A special nurling tool held in the tool post with a parting tool is shown in Fig. 11. The parting tool is clamped under the nurling tool, with its blade shown at *h*. The nurling tool is jointed, so that when the parting tool is used, the nurl *a* may be raised to the position shown by the dotted lines. While the screw is being made, the nurl should be turned back and the parting tool used to cut a shallow notch in the work, which will define the thickness of the head. If the head must be made true, a light cut should be taken with a back tool held in the back tool post. This back tool should be shaped the same as a broad-nosed lathe tool and set in the tool post upside down, so that it will cut on the back of the work when the lathe is running forwards. The stop on the cross-slide should be so adjusted that the tool will just cut the head to the given diameter. The nurling tool may then, by pressure of the hand lever, be forced against the work until the teeth in the nurl roll corresponding grooves in the head of the screw. When the work has been properly nurled, the parting tool is again brought to place and the screw cut from the bar.

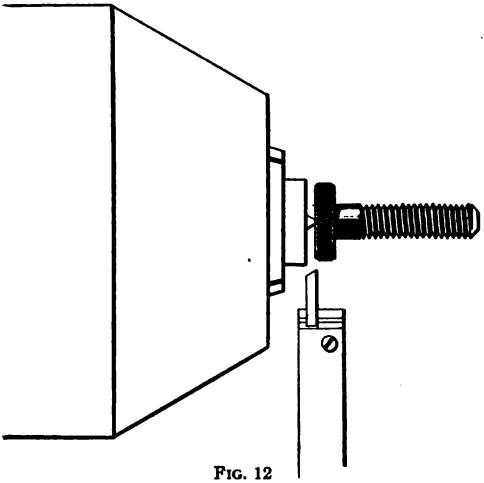


FIG. 12

20. When the parting tool is properly ground and set, it should leave the head of the screw bright and smooth, with no projection in the center. The parting tool, therefore, must be so set that its edge comes exactly in line with the axis of the work. If the parting tool is ground square across its cutting edge, the work will break off before the cut is quite finished. This trouble may be avoided by grinding the cutting edge of the parting tool beveled, as shown in Fig. 12.

Here it cuts a smaller diameter near the head, and will cut the work off clean. The tool is then fed in until it removes the conical point of metal from the stock. The operation of making a screw as just described is but one of a very great variety that may be performed on the screw machine. While certain tools were chosen to perform this operation, other forms of tools could have been used with the same result.

OTHER TURRET TOOLS

21. **Solid Hollow Mill.**—In place of the roughing box tool, a hollow mill could have been used. Fig. 13 shows a solid hollow mill, and Fig. 14 shows a holder used for it. These mills cut on the edges *a*, and are bored to the size that they are intended to turn. As soon as the mill begins to cut, the end of the work at once enters it and is thereby steadied or supported while the cut is being taken. Because of the four cutters on opposite sides of the work, it is balanced so that there is less tendency for it to spring than when only one cutter is acting.

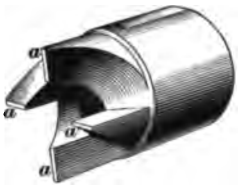


FIG. 13

22. **Adjustable Hollow Mill.**—An adjustable hollow mill is shown in Fig. 15. By loosening the screws at the front and turning the nurled head, the blades *a* can be moved toward or from the center, thus making the cut larger or smaller. The cutting action of this tool is the same as that of the solid hollow mill. The cut is taken on the end faces of the cutter blades, the inner faces acting as guides to support the work after it is turned. As the cut made with a hollow mill cannot be depended on to be perfectly true, a finishing box tool should always be run over it. Finishing tools are made

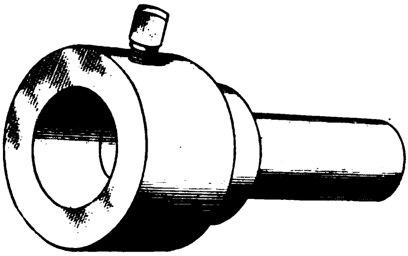


FIG. 14

in a variety of shapes. Fig. 16 shows a style of finishing hollow mill that has two inserted blades *a* that do the cutting; the other two blades *b* are simply back rests to steady the work.

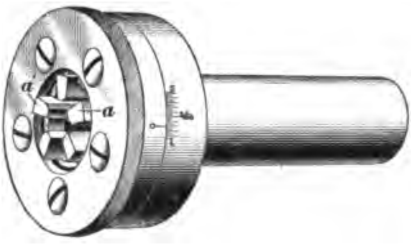


Fig. 15

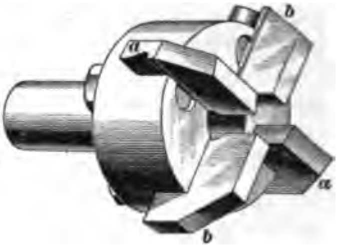


Fig. 16

23. Spring Die.—Besides the solid dies mentioned, other forms are used. Fig. 17 shows a form of hollow spring die that is held in the holder shown in Fig. 10. When in use, this die would tend to spring, so that it is necessary to use a clamp, Fig. 18, that passes around the die and holds it in shape. By means of this clamp, the die may be adjusted to make slight differences in cutting. The objection to this form of die is that considerable time is lost in reversing the machine and backing the die from the work.

24. Automatic Dies.—The difficulties arising from the use of solid and spring dies are overcome by the employment of automatic dies. These dies cut all screws up to 1 inch in diameter at one passage over the work; but for sizes over 1 inch it is better to cut nearly to size, after which the die is returned to the starting point and a second, or finishing, cut is taken over the screw. When the die has fed to the limit of its travel and further movement of its holder or shank is retarded, the die opens automatically and is withdrawn without loss of time. This movement

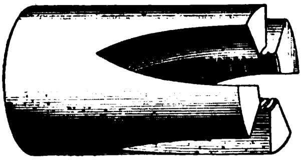


Fig. 17

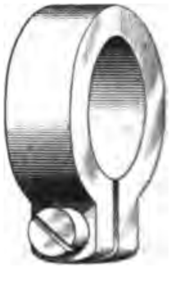
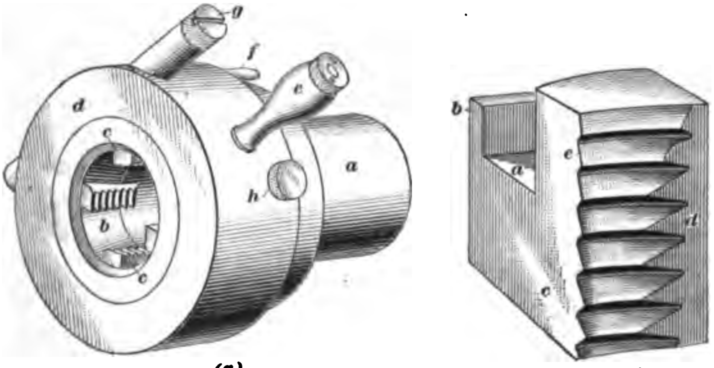


Fig. 18

saves the wear on common dies that results where the work has to be reversed and the die backed off.

25. One form of automatic die, shown in Fig. 19 (*a*), consists of a shank *a* that is gripped in a tool holder on the turret, an internal body *b* that holds the chasers *c* in radial slots, and a cam holder *d*. On the inner face of the cam holder is a cam over which the ends of the chasers fit. When, by revolving the cam holder *d*, this cam is turned, it moves the chasers toward or away from the center, along the radial slots. The shank *a* and the body *b* are held together by driving pins extending from the shank into the body. Thus, when the die is cutting, the body is prevented from turning; but as soon as the turret carrying the die comes against its stop, the continued turning of the work in the die pulls the chasers forwards. The body *b* and the cam holder *d* are consequently drawn away from the shank *a* until the driving pins disengage. A spring inside the cam holder then turns the cam and opens the chasers so that they are free from the work. The die is thus automatically released.



(*a*) FIG. 19 (*b*)

26. The die is closed and set ready for work again by pulling the handle *e*, Fig. 19 (*a*). This handle is fastened to the cam holder that carries the cam. By pulling on the handle, the cam is rotated and the chasers are moved inwards to their cutting positions. Also, this movement of the handle *e* draws the opening spring back again, and allows the driving pins to reengage, thus locking the body *b* to the shank. The die may be closed either by hand or by a trip pin located on the turret slide. The short handle *f* at the back is attached to the cam, and is used when a roughing and a finishing cut are required. The handle is thrown to one side, opening the chasers slightly, and the roughing cut is taken. It is then swung over to the opposite side, closing the chasers, and the finishing cut is taken. The screw *g* is also connected with the cam, and is used when it is desired to adjust the chasers very accurately. One turn of the screw moves the cam very slightly and alters the adjustment of the chasers a correspondingly small amount.

27. Changing Chasers.—The chasers are removed from the die by unscrewing two thumbscrews, as *h*, Fig. 19 (*a*), located in nearly opposite positions on the cam holder. By running these screws out a short distance or pushing in corresponding spring pins in other types of dies, the cam holder may be removed, leaving the chasers free to be taken out. The chasers are replaced in the body after the slots are cleaned by slipping the chasers into the slots having the corresponding numbers and sliding them in so that they meet near the center. The cam holder is then cleaned and pushed back in position, and each of the chasers is thrust out against the cam surface, which allows the cam holder to return to its working position. The screws in the cam holder should enter the holes in the spring collar. The die is closed by pulling the projecting handle *e* and turning the adjusting screw *g* until the lines on the cam and chasers coincide. The die will then cut the approximate size, but the true size, to which the die must be adjusted, should be determined by trial. The construction of the die is such that $\frac{1}{64}$ inch of variation over or under the standard size may be made.

28. Form of Thread Chasers.—The chasers used in the automatic die are made as shown in Fig. 19 (*b*), from a block of tool steel having a notch *a* cut in one end, leaving a projecting shoulder *b* that engages the cam by which the chaser is moved. The teeth are milled with a milling cutter so that they are full on the cutting face *c* and run out on the surface *d* at right angles to the cutting face. The throat *e* of the die is chamfered to form the main cutting edge, and this part and the first three or four teeth are given ample clearance so that they will cut freely. Farther along the clearance at the cutting edge is decreased and the threads are given a decided bearing on those already cut. This causes them to act as a lead-screw nut, which feeds the screw through the die and gives it the correct pitch. The chasers are sharpened by grinding the face *c* slightly. Most of the grinding, however, is done in the throat. A grinding wheel less than 2½ inches in diameter is preferred for this work, and only enough should be removed from the throat of each to correct the wear. The same amount should be ground out of each die in the set.

29. Holding Drills and Taps.—When drilling or tapping is to be done, the drills or taps are held in the turret in the same manner as the other tools. The drills may be held in a chuck provided for that purpose. When the taps are used, a releasing tap holder that works on the same principles as the releasing die holder, Fig. 10, is employed, to keep the taps from running into the work too far and breaking. Many other shapes and kinds of tools may be used in the turret. Those that have been mentioned are the standard tools, and embody the general principle that the work must be supported while the blades are cutting. By following this principle, a great variety of shapes of tools may be designed and adapted to particular classes of work with advantage.

OTHER CROSS-SLIDE TOOLS

30. Forged Forming Tools.—The tools used in the cross-slide perform various operations, the more important of which are the forming of irregular surfaces with forming tools, and the cutting of the finished piece from the bar with the cutting-off tool. The forming tools may be forged from bar steel, and filed or machined to the given form. When so made, they are similar to the forged forming tools used in the engine lathe. The main objection to the filed forming tool is that only a limited amount of grinding can be done before the tool will change its shape.

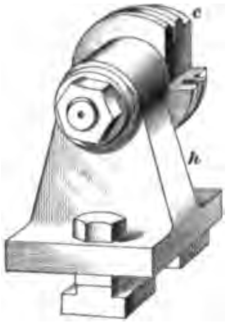


FIG. 20

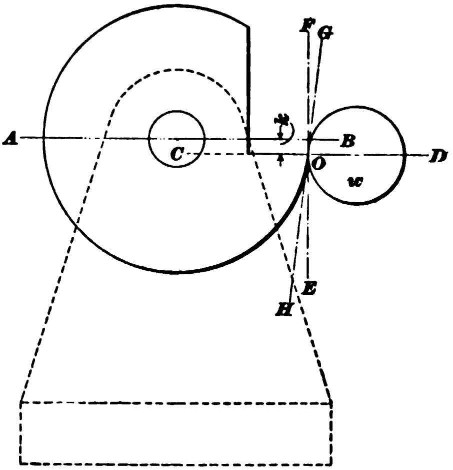


FIG. 21

31. Circular Forming Tools.—To overcome the objections to the filed forming tool and on account of the ease with which the cutters can be manufactured, the circular forming tool has been brought out. Fig. 20 illustrates a typical tool of this class. A circular cutter *c* has been carefully turned and formed so that when a section is taken out at its cutting edge it will conform to the required shape of the work. A notch is cut on one side of the cutter so that the lower face *C D*, Fig. 21, is on a line that would pass slightly below the center *A B* of the cutter. This amount *k* varies with the diameter of the cutter. On a 2-inch cutter, from $\frac{1}{8}$ to $\frac{1}{4}$ inch is sufficient. The holder *h*, Fig. 20, is made of such height that it holds the center of the cutter above the center of the work, thus bringing the top face of the cutter *C D*, Fig. 21, in line with the center of the work *w*. The object of cutting the notch in the cutter below its center and then raising the cutting edge to the center of the work is to give the tool clearance. If the tool and the work are set at the same height, Fig. 22, they will touch at the point *O*, which is in a line joining the centers. If a tangent to the work is drawn through the point *O* and another line tangent to the tool through the same point, the two tangents will coincide in the line *C D*. When the tool is thus set, it has no clearance, and can cut only while it remains absolutely sharp. The circular forming tool has the advantage that it can be ground repeatedly without changing its shape, and it is easier to make than the forged and filed tool.

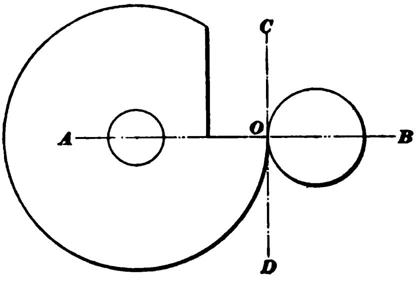


FIG. 22

32. It will be seen by referring to Fig. 21, that if a line *E F* is drawn tangent to the work through the point of the tool, and the line *G H* tangent to the circular cutter at the point, the lines will not coincide as in Fig. 22, but form an angle. The angle *H O E* is the angle of clearance when the tool is thus set. Cutting the face of the notch on the tool below the center will slightly change the outline of the cutting edge, because a section of the cutter on the line *A B* is different from the section on the line *C D*, Fig. 21. If the cutter is 2½ inches in diameter, the difference in section caused by cutting from ⅛ to ¼ inch below the center line will not be sufficient to cause trouble in ordinary work. If an exact outline is required, the cutter must be formed to give the exact outline on its cutting edge and not on the diametrical section. This form of tool is sharpened by grinding the top cutting face, after which the cutter is revolved sufficiently to bring the cutting edge level with the center of the work.

33. Straight-Faced Forming Tools.—Another style of forming tool is shown in Figs. 23 and 24. The heavy cast block, or holder, shown in Fig. 23, is bolted to the cross-slide. In the front side of this tool block is cut a dovetailed slot *c*, into which is fitted the dovetailed part *d* of the forming cutter, Fig. 24. The cutter is clamped to the block by tightening the bolt *e*, which has a special clamp head *f*.

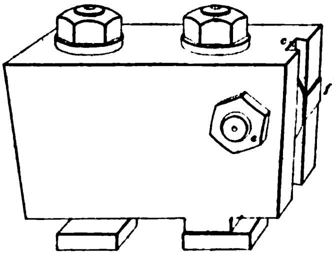


FIG. 23

These forming cutters are shaped along the front edge the same as ordinary forming tools, so that the section across the top cutting face gives the desired outline. They are so set in the holder that the front face *b* has a slight angle of clearance. The top face *a* is ground flat and set at the same height as the center of the work. This form of tool is very rigid. The forming tools just described are so fed to the work that the cutting edge follows in a line that would pass through the axis of the work; thus, in Fig. 21, as the tool advances to take a deeper cut, it moves along the horizontal line *C D*.

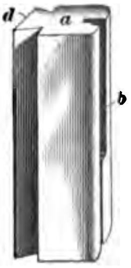


FIG. 24

VERTICAL-SLIDE FORMING TOOLS

34. Vertical Slide for Holding Tools.—Another method of operating forming tools is by means of a vertical-slide rest

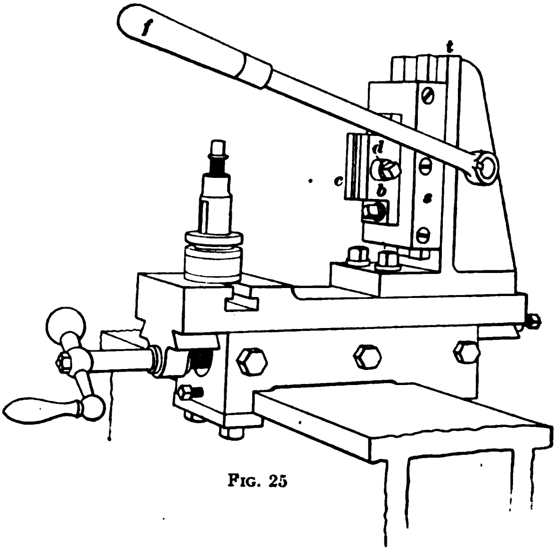


FIG. 25

shown in Fig. 25. Here a vertical slide is clamped to the back of the ordinary cross-slide. When this slide is used with the forming tool, the cutting edge does not move in a line that would pass through the axis of the work, but in a line tangent to the work. Fig. 26 shows a side elevation with the forming cutter *c* in place. The cutting edge follows the line *A B* as the tool moves down in the slide. The cutter *c* is clamped to the block *b* by a bolt *d*. The slide *s* carrying the block *b* travels on the guide *t*, and is controlled by the hand lever *f*. The work is shown at *w*.

35. Form of Tool to Prevent Chattering.—When tools are fed toward the center as in Fig. 21, the entire cutting edge is acting at once. If the cut is complicated or the edge broad, the work will spring and chatter because of the broad cutting edge. When the vertical slide is used, the cutting face of the forming tool may be ground with considerable slope to one side so as to prevent chattering. A tool thus ground is shown in plan and elevation in Fig. 27, and also the shape of the work *w* that this particular form of tool would produce. As the tool is fed downwards past the work, the edge or point *a* will be the first to cut. When the tool is still farther fed along, the point *a* soon cuts to its depth and passes by the work,

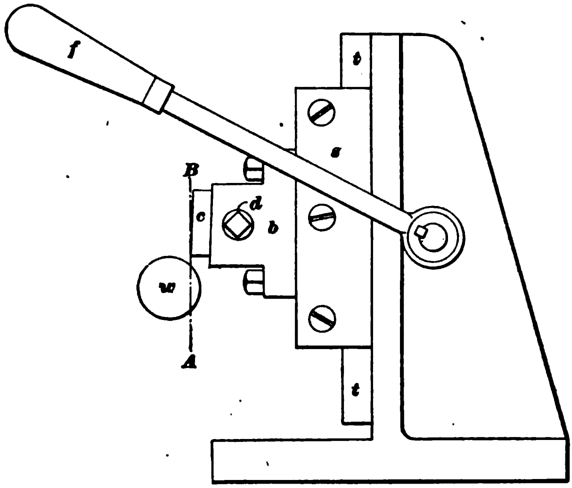


FIG. 26

while other points along the cutting edge are approaching the work. By the time that the last point *b* of the cutting edge has reached the work, the point *a* and all the other points along the edge have passed by, having done their respective parts in the cutting. This method, therefore, permits the use of broad-edged forming tools, since the action is a shaving one, and whatever the total length of the edge of the forming blade may be, only a small part of it cuts at a time. This same principle is used on tools that work on a horizontal slide and cut on the under side of the work.

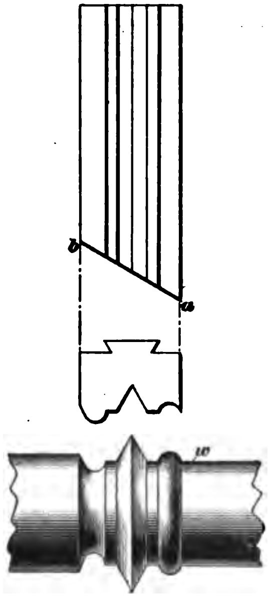


FIG. 27

SPECIAL FORMING HEADS

36. Arrangement.—When very much forming is to be done, and greater production is required than can be obtained by the use of the forming tools just described, a special forming head is used that holds two forming cutters, one at the front and the other at the back of the work. Such a forming attachment is shown in Fig. 28. The front and back forming blades *a* and *b* are held in place in tool blocks *c* and *d* that slide in the base *e* and that are operated by the same screw, which has a right-hand thread at one end and a left-hand thread of equal pitch at the other. By turning the hand wheel *h*, the blocks *c* and *d* advance or recede from the work at a uniform speed. When in use,

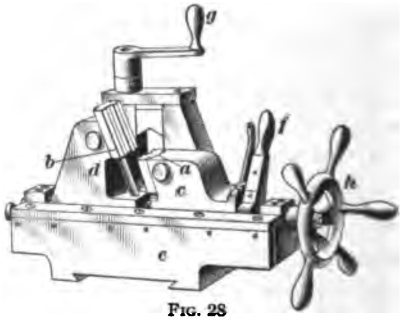


FIG. 28

the blocks and blades are so adjusted that each forming blade is cutting to the same depth. The hand wheel *h* is then turned until the blades have entered the work the necessary depth.

37. Form of Blades.—In the forming attachments using two forming blades, the edges of the blades are not exactly alike. In this case, the back tool *b* may be of the complete outline; the front tool *a* is similar, but has notches cut along its face. This is shown in Fig. 29, where the cutting edges of the forming tools are compared. The back tool *b* has a regular outline, but the edge of the front tool *a* is slightly broken. The result is that the shaving is broken, the high parts of the front tool doing the cutting at the points *i*, and the back blade taking all the remaining parts. The strain on the work and the cutters is very much relieved. When the work is nearly completed, the front blade is slightly backed away from the work by moving the lever *f*, Fig. 28, allowing the tool at the back to finish the work smooth. When two cuts are thus taken the work is quite well balanced, but to steady it still further, a steady rest with V jaws, operated by the crank *g*, is used. These types of forming attachments are extensively employed in bicycle making on such work as hubs, cones, spindles, pedal pins, and similar pieces that are cut from the solid bar.

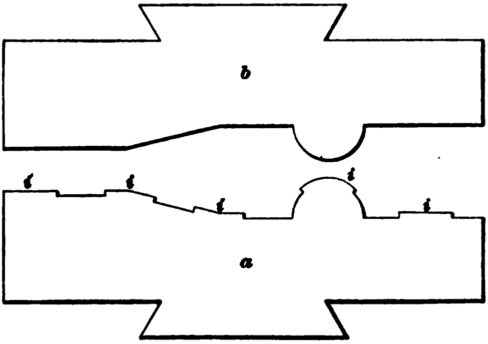


FIG. 29

SPECIAL PARTING TOOLS

38. Inverted Parting Tool.—Instead of the regular parting tool held in the tool post for cutting off the finished work, a special holder for blades may be used, as shown in Fig. 30. This tool is intended to be employed at the back of the machine;

consequently, the blade is inverted, with the cutting edge at *e*. By holding the cutting blade sloping, as here shown, the tool will have top rake, which will add to its efficiency.

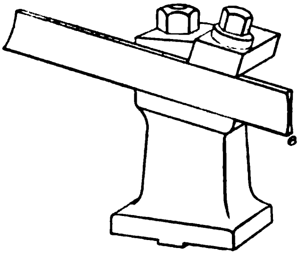


FIG. 30

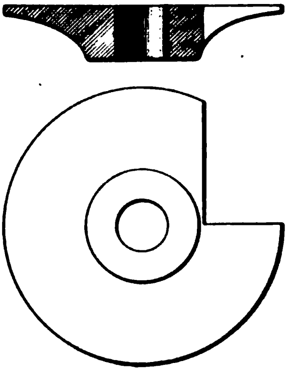


FIG. 31

39. Combined Parting and Forming Tool.—When the head of the piece to be cut off is curved, as in the case of round-headed screws, circular forming tools may be employed.

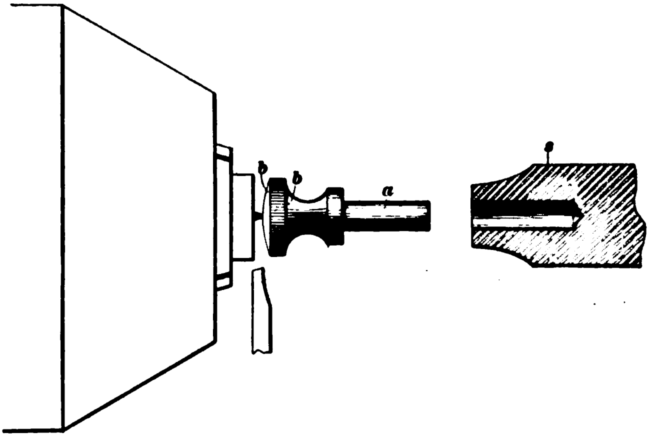


FIG. 32

Fig. 31 shows a section through a circular forming tool that could be used for a cutting-off tool, and at the same time be a forming tool for the head of the work.

40. Steady Rest for Turret Work.—In some cases, a steady rest must be used in the turret for supporting work. Suppose the piece shown in Fig. 32 is to be made. The body *a* would first be turned to size. A hardened-steel sleeve *s*, shown in section, which has been bored to fit over the part *a*, would then be slipped over it by moving up the turret. This supports the work while the head *b* is being formed and the work cut off. This method of supporting the end may be applied to many classes of work.

UNIVERSAL MONITOR LATHE

41. Description.—Another class of turret lathe that is extensively used for brass work and for work that is not made on the ends of rods, is the monitor lathe, shown in Fig. 33. This style of lathe lacks the rod feed and bar chuck found on the regular screw machines. The work performed by the monitor lathe is usually held in a chuck of some special form designed for the particular work at hand. The turret is mounted on a double slide, so that it can move along the line of centers, or at right angles across the lathe to make facing cuts. This gives a combination of two movements for the turret that is not used on the screw machines.

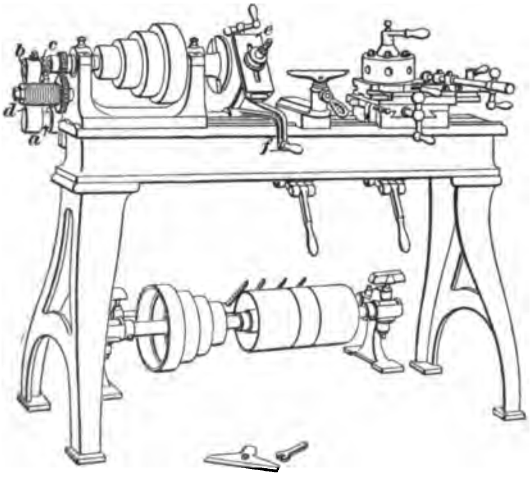


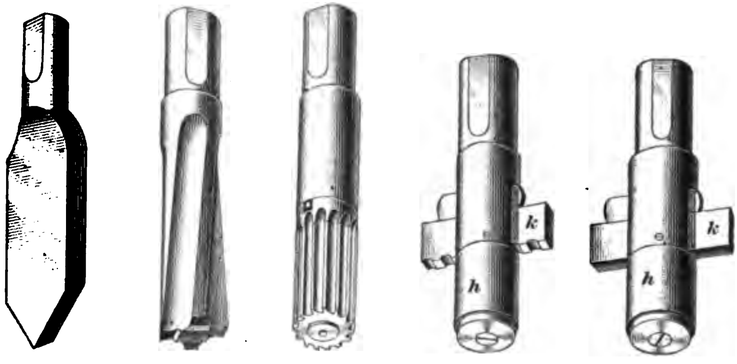
FIG. 33

42. Chasing Threads.—Besides the method of cutting screws by holding dies in the turret, this lathe has a special attachment for chasing threads. At the back of the lathe, nicely fitted to bearings at either end of the lathe bed, is the large round chaser bar *a*, Fig. 33, which is free to move in the direction of its length. To the headstock end of the chaser bar an arm *b* is rigidly attached. On the end of the arm *b* a piece *c* is fastened, on which a few threads are cut similar to those in a half nut. These threads engage with the screw *d*, seen on the stud of the lathe. When thus engaged, as the lathe revolves, the threads on the piece *c* follow the threads in the screw *d*. This motion tends to feed or draw the chaser bar *a* through its bearings. To stop the feed, it is only necessary to lift the arm and the threads *c* away from the screw *d*. The bar can then be moved back to its starting point. Near the center of the bar a slide rest is attached, as shown at *e*. Extending over the bed to the front is a lever *f* to be operated by hand.

43. Suppose that a center is put in one of the turret holes and the work held between centers to have a thread cut or chased. The tool is adjusted in the tool post of the slide *e*, Fig. 33, so that it just touches the work when the piece *c* is against the screw *d*. As the lathe revolves, the tool is drawn along and a thread of the same pitch as the screw *d* is chased on the work. When the necessary length of thread has been chased, the lever *f* at the front of the bed is lifted, the tool being thus raised from the work and, at the same time, the piece *c* from the screw *d*. The bar is then moved back to the starting point, the tool moved forwards a little on the slide *e*, and the lever *f* is again dropped until the piece *c* engages with the screw *d*, when the second cut may be taken. This operation is repeated until the required depth of thread has been chased. Only short threads can be cut by this method, and the screw *d* must be changed for every different pitch. These screws *d* are, in reality, shells that fit over the spindle, or stud. They are made with various pitches of threads and are variously called *leaders*, *hobs*, or *master threads*. This method is extensively used in cutting the threads on brass pipe, valves, and similar work.

SPECIAL FORMS OF TURRET LATHES

44. Turret Applied to Engine Lathe.—For chucking operations, the turret may be applied very easily to an ordinary engine lathe. Suppose that a great many pulleys are to be bored and the hubs faced. Instead of changing the tools in the tool post each time it is used for boring and reaming, if a turret is used each tool can be kept in its place, much time being thus saved. Fig. 34 shows a set of tools that may be used in the turret on an engine lathe for such work as boring and facing pulleys. The tool shown in (*a*) is a flat drill used to remove the scale from a cored hole and to prepare the hole for the chucking reamer shown in (*b*). A fluted shell reamer for finishing the holes to size is shown in (*c*), and in (*d*) and (*e*) are shown facing tools whose ends *h* have been turned to just fit the bore of the pulley, and to steady the tool while the blades *k* are cutting. The edges of the roughing facing tool shown in (*d*) are nicked to break the shaving; the cutter blade of the finishing tool shown in (*e*) has a straight edge.



(*a*) (*b*) (*c*) (*d*) (*e*)

FIG. 34

45. Turret Applied to Heavy Work.—Another application of the turret to the lathe is shown in Fig. 35. In this case an octagonal turret takes the place of the saddle. The turret moves automatically along or across the bed by power feed and has the same motion as an ordinary tool post in the lathe. In the illustration, an engine cylinder head 22 inches in diameter is being finished. Special chuck jaws hold the work to the face plate, and the blocks *a*, which have been faced off after being bolted to the face plate, aid in setting the work true with the face plate. The turret has flat faces on its sides, so that special tool holders can be clamped to it. By the use of these holders, facing, turning, and boring tools may be held in the turret and brought in quick succession to perform their respective duties. A special slide is supplied, when required, to take the place of the tailstock. This makes a turret lathe out of the engine lathe.

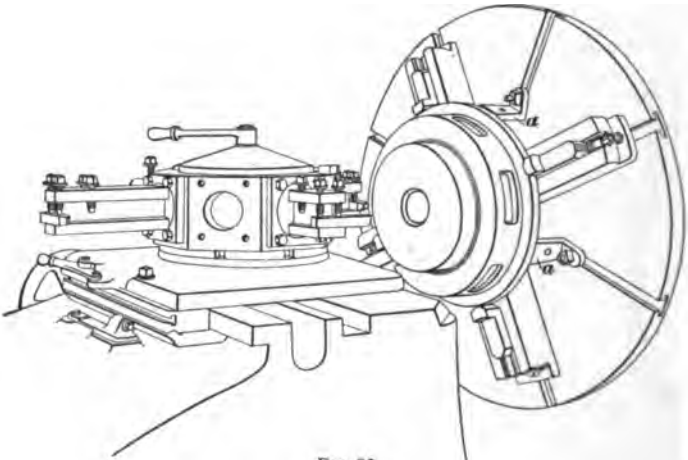


FIG. 35

46. Special Turret Lathe for Heavy Work.—A chucking lathe designed for the heaviest class of work on castings or forgings is shown in Fig. 36. The machine is massive in design and its power is sufficient to take the heaviest cuts. Special forms of tools and cutters are required for this as well as for all turret lathes before work of any kind can be done; but, once the machine is equipped with a set of tools designed for a special purpose, its productive capacity is very great. If the number of like pieces to be finished is small, it will rarely pay to install one of these machines; but if a considerable number of pieces of any special design are to be made, such a machine will be a valuable addition to the shop equipment.

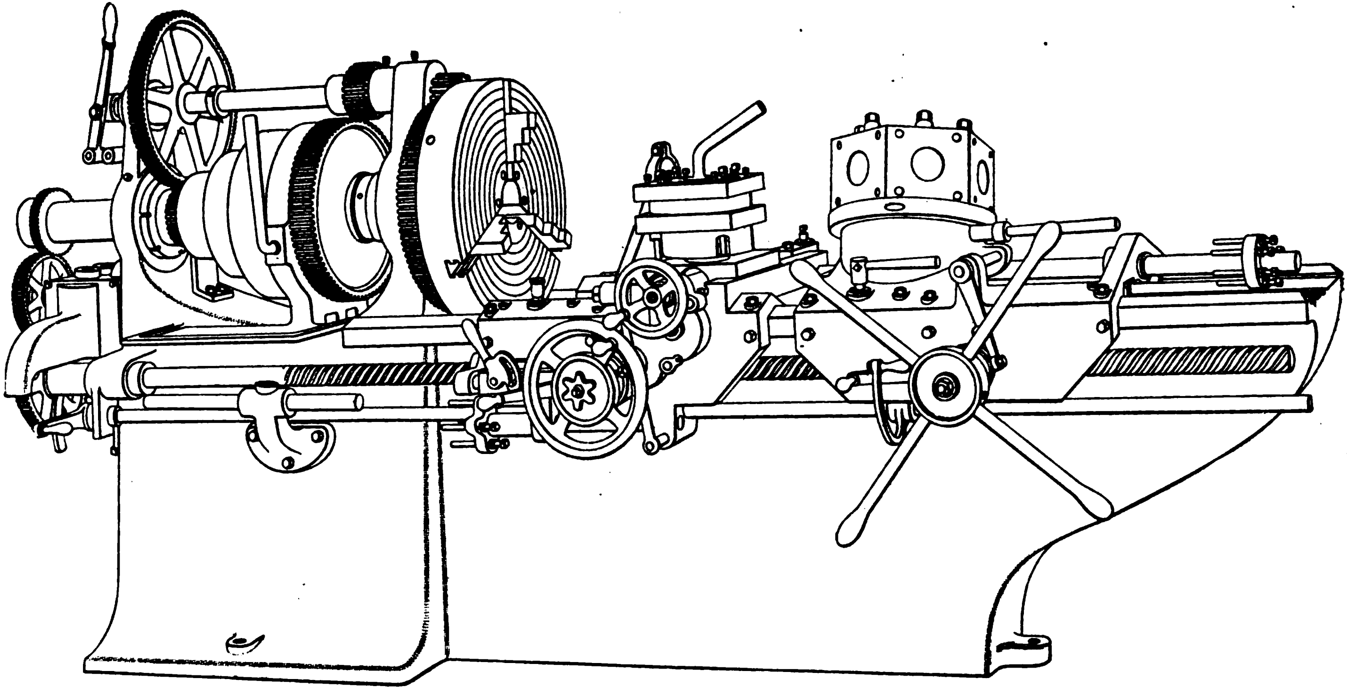


FIG. 36

47. Boring Cone Pulleys.—Fig. 37 illustrates the lathe shown in Fig. 36 fitted up to bore a cone pulley *k*. The hub is roughed out by a cutter on the bar *c* and finished by the cutter on the bar *d*. The steps of the cones are bored and the faces finished by the special tools *a* on the bar *b*; the outer edge of the pulley is faced and a finishing cut taken on the inside of the largest cone by the heads *e* and *f*. All the tools are provided with extensions on the ends of the bars; these fit bushings in the spindle of the machine or the chuck and thus furnish a guide for the end of the bar. The stiffness of the tool and the effectiveness of the machine are thereby greatly increased. At *g* a series of screws are arranged to act as stops for the various tools, each one of which can be adjusted separately. In the illustration, the carriage *h* and the taper attachment *i* are not in use. These cone pulleys may be finished on the outside on the same machine by mounting them on suitable arbors and turning them with special tools placed on the carriage *h*. This example is given simply as an illustration of the class of work for which this style of machine is adapted.

48. Flat Turret Lathe.—The flat turret lathe shown in Fig. 38 consists of the usual bed *a* carried on a pan *b* to catch chips and oil. It is operated through a geared head *c* that has, in addition to the usual movements found in a lathe head, a sidewise movement on slides planed at right angles to the carriage **V**'s. The sidewise movement of the head is used when radial cuts are made. A lever *d* operates the bar chuck. The lever *e* controls the back gears, giving three speeds, and the lever *f* may be employed to give the additional required geared speeds. A plain carriage *g* carries the flat turret and tools on its top; it is operated through the apron *h* at the front of the lathe. A feed-rod *i* moves the carriage by power through suitable gearing; but the carriage may also be moved by hand by use of the capstan wheel *j*. The finished work is cut from the bar by a cutting-off tool operated by the tool lever *k* on the turret. The capstan wheel *l* is used to operate the cross-feed by hand. The automatic feed of the carriage is thrown in and regulated by the lever at the front of the carriage; and nine different

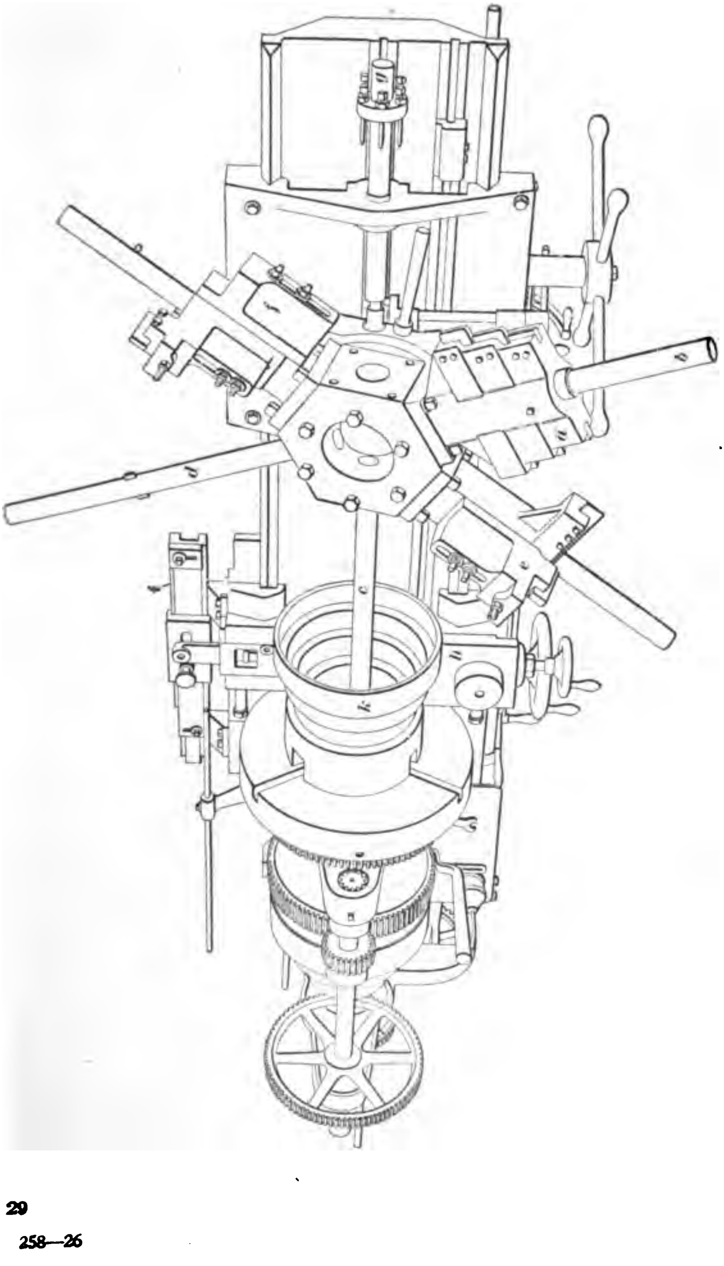


FIG. 37

feeds may be obtained by moving the lever *m*. A belt-driven oil pump furnishes oil to the cutting tools from the oil reservoir in the bottom of the pan. The head is driven by a belt running on the pulley *n*, and the shifter *o* provides for starting, stopping, and reversing the spindle.

49. Comparison of Engine Lathe and Turret Lathe. In the turret lathe there are several holders in which are set a number of tools that are brought in succession against the work, so that the operations of the tools follow one another, and these operations can be repeated without resetting the tools. The turret lathe is thus enabled to do duplicate work. With the regular engine lathe, duplicate work depends entirely on the skill of the operator. The carriage has a larger bearing and the tool holders are heavier on the turret lathe than on an engine lathe that would be used for the same class of work, insuring greater rigidity. Again, the turret lathe works more nearly automatically than the engine lathe. Long work can be passed through the spindle of the turret lathe and through the turret, and thus can be handled more readily than on the engine lathe. Also, bar stock can be fed in one piece to the turret lathe, the cutting off being done by the lathe itself; whereas, with an engine lathe, the bar would first have to be cut in pieces of the required length.

50. Geared Head.—The head of the lathe shown in Fig. 38 contains the back gearing and the speed-changing gears, by which the rate of turning of the spindle may be altered. The handle *e* is used to put the back gears in action and the handle *f* controls other gears that give additional speed changes to the spindle. An ordinary chuck is screwed on the spindle for plain chuck work; but an automatic chuck is placed on the spindle when bar work is to be done. The bar chuck grips the bar from which the work is to be made, and when the operation is completed the movement of a lever opens the chuck and starts the roller feed. Stock having any form of cross-section may be held in the chuck, but a set of jaws conforming to each section must be used.

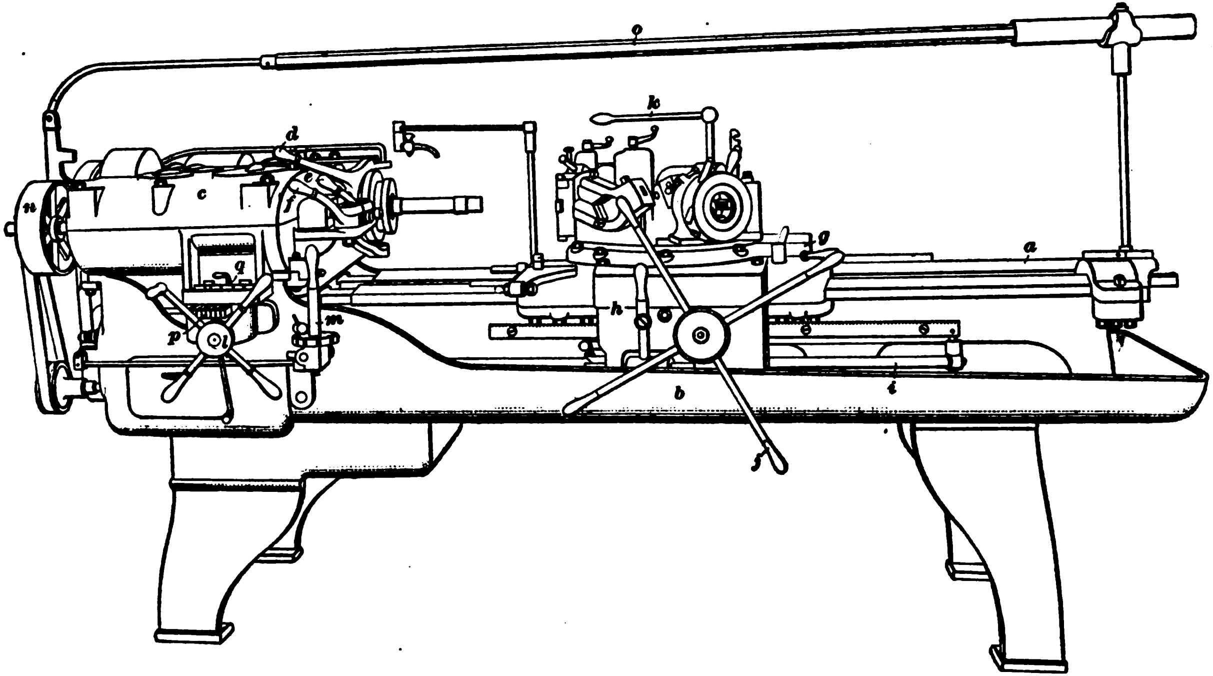


FIG. 38

51. Roller Feed for Bars.—While the lathe is in motion the bar is fed through the spindle by the roller feed shown in Fig. 39. In the illustration, the outer shell and the bearings of the shafts are shown transparent, so as to make the inner construction plain. The outer shell, which carries the bearings of the shafts to which the gears are fixed, is fastened to the lathe spindle and turns with it. While the operation is being performed, the outer shell, the spiral gear *a*, and the spindle all rotate together, and the gears inside the shell have no relative motion. But when the bar chuck is opened a pin is pushed forwards and catches one of the lugs on the outer face of the gear *a*, preventing this gear from turning. The shell of the roller feed continues to turn with the spindle, and consequently two spiral gears *b* are turned by being moved along the edge of the stationary gear *a*. Each of the gears *b* is on a shaft that carries a right-hand worm *c* and a left-hand worm *d*. The worms in turn rotate the worm-gears *e* and *f* that cause the rolls *g* to feed the stock or bar through the spindle. The rolls are adjusted to their proper working distance by two screws *h*. A scroll chuck at the back of the roller feed brings the bar central with the spindle and the rolls are set in motion, when the bar chuck is opened, by the same lever that opens and closes the chuck. The bar is fed up against the stock stop where it is held by the rolls until the chuck is closed, which stops the roller movement.

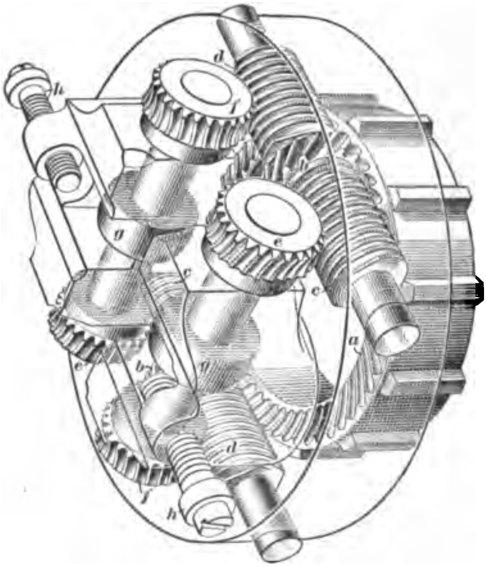


FIG. 39

52. Roller Turner.—A form of roller turner is shown in Fig. 40. The cutting tool *a* is clamped firmly in the block *b* by the setscrews *c*, and the work to be turned passes between the tool and the rollers *d*. The work thus rests against the rollers while the tool is cutting. The block *b* is movable, its position being controlled by a lever *e* and thus two different diameters may be turned with one tool. When the lever is thrown forwards as far as it will go the tool is in its farthest position from the rollers and cuts to the greatest diameter on the work; but when the lever is drawn back to the position shown, the tool is forced closer to the work and cuts to a smaller diameter. The travel, or swing, of the lever is adjusted by the screws *f*. The rollers are held in brackets and may be swung closer together or farther apart by turning the handle *g*, thus setting them to suit different sizes of work. Also, the rollers may be moved sidewise on their pins, so that they bear either on the part that is to be turned or on the part that has been turned; that is, they are not directly opposite the tool. The positions of the rollers can be adjusted very accurately by setscrews at the back, but not shown in the illustration.

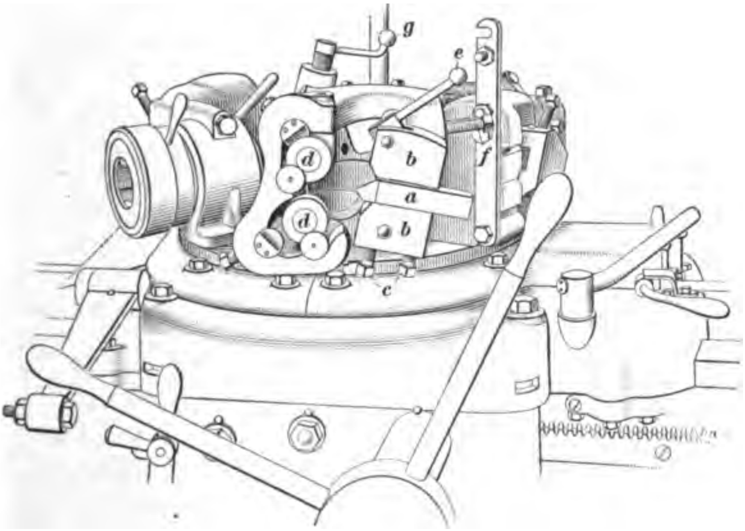


FIG. 40

53. Construction of Flat Turret.—The flat turret *a*, shown partly in section in Fig. 41, consists of a flat circular plate that rests on a flat bearing on the carriage *b*. It is held in place by the center pin *c* on which it rotates and by the circular gib *d* that is screwed to the carriage. The tool holders have tongues on their lower surfaces, and these tongues are set in the slots *e* in the plate *a*, after which the holders are bolted firmly to the plate. The turret is rotated on the pin *c* to bring each tool into position for cutting. The rotation is accomplished by turning the pilot wheel and running the carriage back until the end of the rack *f* strikes a back stop fixed to the bed of the lathe. As the carriage continues to move, the rack is pushed into the turret and the end *g* strikes the pawl *h* on the lever *i*, which is pivoted at *j*. The lever is thus forced down, and its free end pushes the pin *k* down and thus frees the turret plate *a*. The latch *l* then hooks over the lever *i* and holds it down while the plate is being turned.

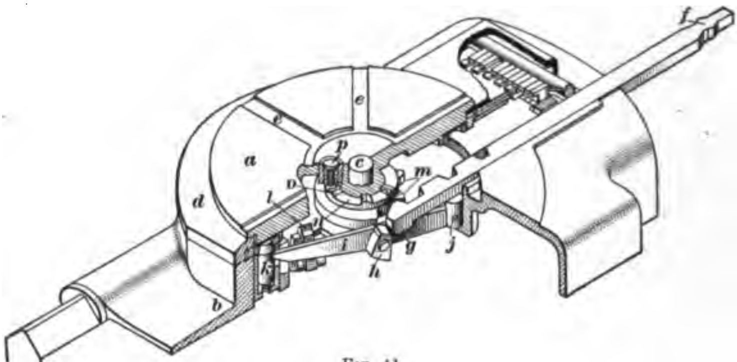


FIG. 41

54. The turning of the plate *a*, Fig. 41, is done by the rack *f*, which is notched so as to engage the teeth *m* on the ratchet gear *n*. The rack is held stationary by the back stop, and the movement of the carriage brings one of the teeth *m* of the ratchet gear *n* against the rack and so turns the gear. The projection *o* on the upper face of the ratchet gear catches the pin *p* and thus turns the turret plate *a*. When the plate has turned almost to its correct position, a screw not shown in the illustration strikes the latch *l* and unhooks it from the lever *i*, thus allowing the pin *k* to be forced up by the spring beneath it. When the turret rotates to its proper position, the pin *k* springs up into a hole or bushing in the under side of the turret plate and locks it in place. The tool is now fed up to the work by turning the pilot wheel. As the carriage is moved up, the rack *j* is held for a moment by a clip that fits over the lugs at its outer end. The rack is thus pulled out again to the position shown, ready for the next rotation of the turret. When the rack is thus moved out, the ratchet gear *n* turns backwards freely under the pin *p* without moving the turret. When the carriage has moved forwards far enough to return the ratchet gear to its original position, the rack strikes a stop on the carriage and is brought forwards with the carriage and thus drawn away from the clips.

55. Stop Systems.—In the flat turret lathe shown in Fig. 38, the movement of the carriage, and consequently the travel of the tool, is limited by a system of stops and stop-bars, as shown in Fig. 42, in which (*a*) is an enlarged view of a part of the mechanism shown in (*b*). The stop-bars *a* consist of twelve rectangular bars, known as A stop-bars and B stop-bars. One of each corresponds to each of the six divisions of the turret, as indicated by the numbers A 1 and B 1, A 2 and B 2, etc. The object of using two stop-bars for each division of the turret is to allow two successive movements to be given to a tool during one operation. Above the ends of the stop-bars is a series of twelve stop-bolts *b*, one for each bar, known as A stop-bolts and B stop-bolts, and standing vertically in a slot in the carriage *c*. The upper end of each bolt is formed with a **T** head, and a lifting crank *d* pivoted on the carriage has a tongue that fits under the **T** heads of each pair of stop-bolts; that is, there are six lifting cranks to the twelve stop-bolts. Behind each lifting crank and bearing against its back face is a tappet rod, one of which is shown at *e*. This tappet rod extends from the crank to the face *f* of the turret.

56. While the turret is being turned, one end of the tappet rod *e*, Fig. 42, bears against the circular face *f* and the other end presses against the lifting crank, holding it up and thus

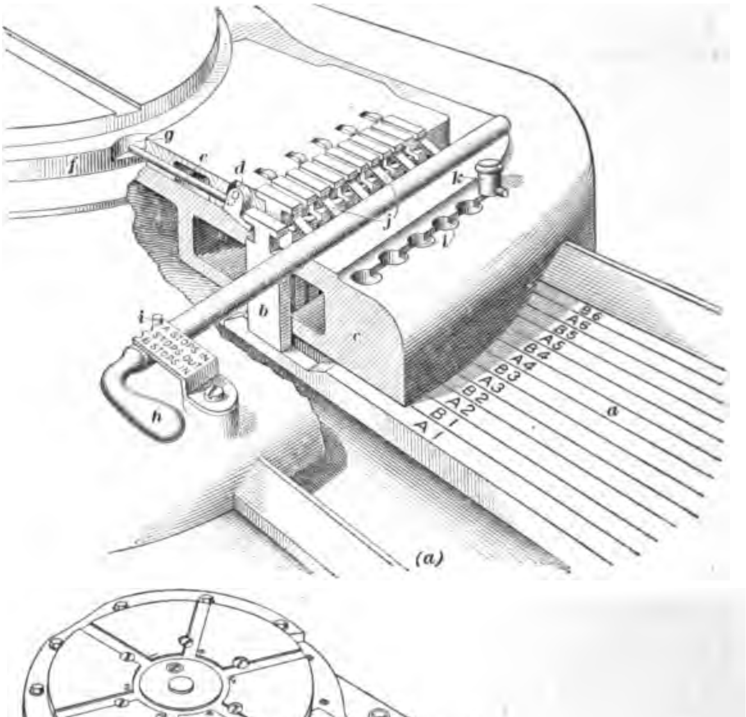

g
f
e
d
k
j
l
b
c
i
h
A STOPS IN
STOPS OUT
B STOPS IN
A1
B1
A2
B2
A3
B3
A4
B4
A5
B5
A6
B6
a
(a)
g
d
k
e
f
j
l
i
b
c
h
a
m
n
(b)

Fig. 42

preventing any of the stop-bolts from dropping lower in the slot. When the turret has turned so as to bring the tool in the first section to the proper position, the pin *k*, Fig. 41, springs into its bushing and locks the turret in position, as already explained. When the turret reaches this position, the recess *g*, Fig. 42, stands opposite the end of the tappet rod *e*. The A 1 stop-bolt *b* then falls of its own weight, turning the lifting crank *d* and forcing the end of the tappet rod *e* into the recess *g*. The stop-bolt *b* now rests on top of the A 1 stop-bar, and the turret is locked in position with the tool clamped in its holder in slot 1 ready to perform its work. The carriage is now moved up toward the headstock, thus bringing the tool against the work. During this movement the stop-bolt *b* simply slides along the top of the corresponding stop-bar; but as it comes near the end of the stop-bar it falls into the notch cut in the upper surface of the bar. Further movement of the carriage brings the stop-bolt against the square shoulder, as shown, and the movement of the carriage is stopped; in other words, the meeting of the stop-bolt and the shoulder of the notch in the stop-bar determines how far the carriage shall move, and therefore how far the tool shall travel.

57. If only one stop is used for each numbered section of the turret, it will be necessary to employ only six stop-bars and stop-bolts. The other six stop-bolts are then held out of action by a simple device consisting of a series of lifters operated by a handle. In the particular case shown, the A stops are being used, and the handle *h*, Fig. 42, that controls the lifters is set so that the pin *i* in the rod attached to the handle is in the notch marked A STOPS IN. Along the sides of the rod are six lifters *j* that fit under the T heads of the six B stop-bolts and hold them up, so that they cannot drop even when the tappet rod enters the recess in the turret plate. In this way only the A 1 stop-bolt will act to stop the travel of the tool on section 1 of the turret. If two stops are used on one section, as section 1, the handle *h* is first set as shown, and the A 1 stop is used. Then the handle is moved so that the pin *i* is in the slot marked B STOPS IN, and this throws the lifters *j* under the A stop-bolts and allows the

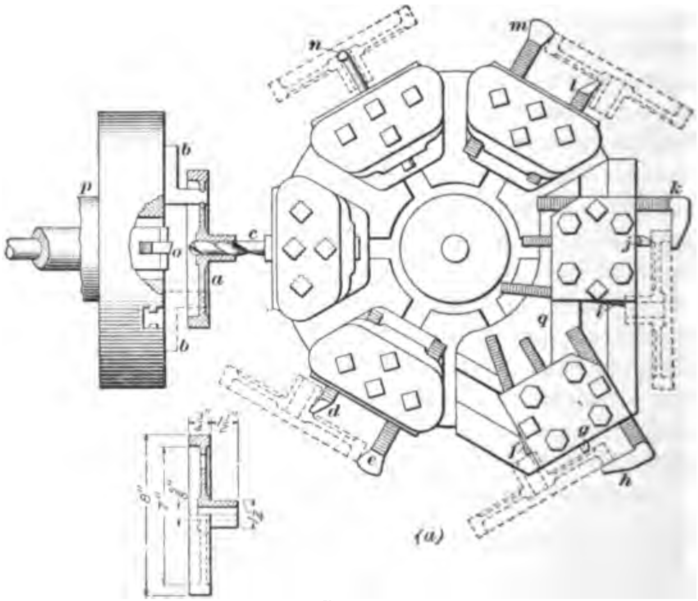
B stop-bolts to act so as to limit the travel of the tool for the next cut. The action of the B stop-bolts is exactly the same as that of the A stop-bolts. If it is desired to prevent either set of stops from acting, the lever *h* is turned so that the pin *i* is in the central notch. This process moves one of the lifters *j* under each pair of stop bolts, and none of them can drop.

58. There are six tappet rods like *e*, Fig. 42, one corresponding to each lifting crank. Also, there are six recesses like *g* in the turret plate, one for each section of the turret, and these recesses face up and down alternately. When the turret is turned and one of these recesses swings past the ends of the tappet rods, the weight of the stop-bolts forces the tappets into the recess, one after another. But the recess has sloping sides, so that, as the turret continues to turn, the tappets are forced out again, lifting the stop-bolts that have dropped. When the turret reaches its new position and is locked by the pin under the turret plate, a recess is opposite the end of the tappet rod corresponding to that particular section, and the tappet rod moves into it. The other five tappet rods now bear against the face *f*, and so keep the other five lifting cranks from turning, which in turn prevents their stop-bolts from dropping. The six recesses in the turret plate are not equally spaced around the plate, but are cut so that each is opposite the proper tappet rod when its corresponding turret section is in use. After a stop-bolt has acted to stop the carriage it is lifted to its original position either by shifting the handle *h* or by turning the turret to a new position, which would force the tappet rod out of the recess and so turn the lifting crank and raise the stop-bolt.

59. If more than two stops must be used to give the desired movements to a tool, the auxiliary stop-pin *k*, Fig. 42 (*b*), may be placed in one of the holes *l* so as to act on one of the B stop-bars that is not in use with the A or B stops. This pin is put in and removed by hand, and acts in the same way as a stop-bolt; that is, it rides along the stop-bar until it falls into the notch and stops the carriage. If the carriage is to be stopped while feeding backwards, or away from the chuck or headstock, the stop-bar should be turned upside down, so that the stop-bolt will come against the squared end. Each stop-bar is adjusted with the turret turned to its proper position and the tool run to the limit of its cut. The position of each bar after adjustment is maintained by tightening the setscrews *m*, and after all the bars are set, they are clamped tightly by the screw *n*.

60. The stop system just described limits the travel of the tool parallel to the **V**'s of the lathe. A system of stops is also used in connection with the movable head, which is so arranged that it can be moved at right angles to the **V**'s. This movement enables shoulders to be cut and facing cuts to be made. The cross-stops for the head consist of nine rectangular notched bars *p*, Fig. 38, set crosswise of the bed under the head. They resemble the stop-bars already described and are set in a similar manner. There is only one stop-bolt, however, as at *q*. In the casting above the stop-bars are nine bushed holes corresponding to the bars. The stop-bolt is dropped by hand into any desired hole, and the pin then rides on the bar until the head is moved as far as it should go, when the bolt drops into the slot in the bar and prevents further motion. The notches in the bars have square shoulders at both ends, and the bolt may be used to stop the motion of the head in either direction. The stop-bolt must be shifted by hand for each different movement of the head. There is an arrangement by which the head may quickly be brought to a central position for bar work or similar work.

61. Flat-Turret Chuck Work.—An illustration of the order in which a number of operations are performed on a piece of chuck work and the tools used to make the cuts is shown in Fig. 43 (*a*), and the dimensioned cast-iron piece is shown in (*b*). The piece *a* is gripped by special chuck jaws *b* with the head set central. The first turret tool to be used is the twist drill *c* to form the central hole, thus bringing one turret stop into use. In the second operation two tools *d* and *e* are used; the first is set to rough turn the hub and the other to turn the outside of the rim. One turret stop is required in this operation to determine the length of hub to be turned and one head stop with the head set far enough to the rear of the machine to enable the tools to make the two cuts. The third position of the turret shows three facing tools *f*, *g*, and *h*, two straight and one bent, rough facing the outer end of the hub and the two sides of the rim. One turret stop and one head stop are required in this operation, which completes the roughing cuts on six different surfaces. The fourth turret section has three tools *i*, *j*, and *k*, similar to those used on the third section and which are employed in the same manner to finish the three surfaces at once, both turret and head stops being used. In the fifth turret operation two tools *l* and *m* similar to those used in the second operation are used; they finish the two surfaces roughed in the second operation. The sixth turret section holds a special cutter *n* for finishing the hole by one cut. The turret operations are thus completed on six different surfaces with twelve cuts. The work is completed by feeding a facing cutter *o* against the inside end of the hub. The facing cutter is on a shank passed through the hollow spindle *p* and is kept from rotating by a hand lever that is also used to feed the cutter against the hub.



(b) FIG. 43

62. The piece of work shown in Fig. 43 was completed in 10 minutes, with thirteen different cuts. Each tool is made of a size proportionate to the work it has to do and the distance it will extend unsupported beyond the turret. The bent tools used on the third and fourth sections of the turret must extend farther than the others; so a special extension plate *q*, to which the tools are secured, is bolted to the turret. Each tool is so set that it has the least possible overhang, insuring rigidity; also, each one lasts much longer, because it is employed for only one part of the work.

AUTOMATIC SCREW MACHINES

63. Characteristic Feature.—The automatic screw machine is distinguished by the fact that its movements are made automatically instead of by hand. A series of cams and levers control the working of each part of the machine. The introduction of the automatic control makes the machine much more complicated than the simple hand machine.

64. Setting Up Automatic Machines.—Whenever a piece of a certain shape is to be made, a special cam must be designed that will give the proper movements to the parts. A specially designed cam and a new arrangement of tools is required for every new shape of work. These factors also vary for each make of machine. The cutting tools are the same in principle for the automatic as for the hand machines; hence, no special description is necessary.

65. When to Use Turret Lathes.—Before a piece of work can be successfully made on a turret lathe, some special fixtures must be made and the machine adjusted; it then produces finished pieces much faster than the engine lathe. In determining whether it is profitable to use the hand turret or the automatic turret lathe the amount of finished work to be produced must be considered. It will not pay to make special tools, or even to take the time to set up an automatic turret lathe unless the number of pieces to be finished is large enough that the saving in time overbalances the cost of making special tools and fixtures. The hand-turret lathe may be employed for a moderate number of pieces; but if there are only a very few, a chucking machine or the engine lathe should be used.

SPECIAL FORMS OF LATHES

TOOLMAKERS' LATHE

66. General Description.—The term toolmakers' lathe is applied to lathes of the form shown in Fig. 44 having from 10 to 16 inches swing. In appearance, it is similar to the regular screw-cutting engine lathe. It is equipped with taper attachment, compound rest, and special chucks, and is made with a greater degree of perfection than is the ordinary engine lathe.

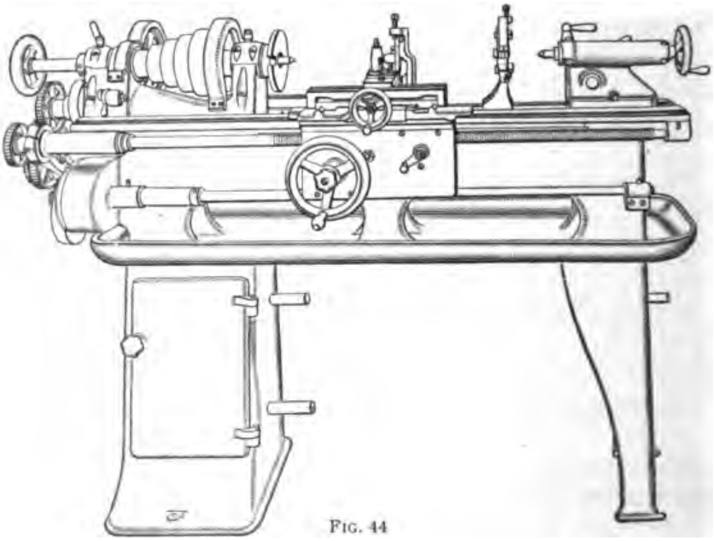


FIG. 44

67. The carriage of the lathe shown in Fig. 44 has a plain rise-and-fall rest which has the advantage of being more quickly adjusted for height of tool and for turning to size than the rest commonly used. The tool rest consists of a **T**-shaped casting

ied on two V's on the carriage at right angles to the V's
ıe bed. A vertical screw through the back end of the slide
ves to raise or lower the back end any required distance. This screw also furnishes a very delicate means for adjusting the setting of the tool when turning to size, as it has no backlash. The slide is held down by a spiral spring, one end of which is fast to the T slide and the other to a projection extending down from the bridge of the saddle. The larger sizes of toolmakers' lathes are provided with gear-box feeds, carriages of the gib form, and with motor and geared-head drive, as may be required.

68. The live spindle of the lathe illustrated in Fig. 44 is shown in Fig. 45. The nose is threaded, as shown at *a*, and the remainder is turned parallel, as indicated by the dotted lines *b*. A conical bushing *c* is placed on the parallel part and the face and chuck plates are bored tapering to fit the tapered bushing. The advantage of this construction is that the face plate is drawn up tightly by the thread against the taper on the bushing, which centers the face plate or chuck very accurately and holds it rigidly.

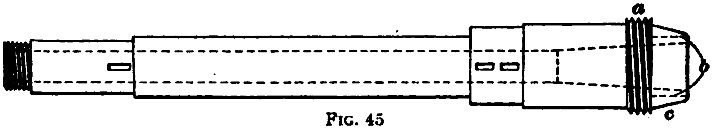


FIG. 45

69. Special Chucks.—On toolmakers' lathes special chucks are used for holding rods or bars of different sizes. They are similar in principle to those used on turret screw machines. The collets shown in Figs. 2 and 3 are known as *push-in collets;* that is, they are pushed into a taper hole to close them. Another style of collet that works on the same principle is the *draw-in collet*, in which the bevel on the large end slopes in an opposite direction to that shown in Fig. 3, so that, to close the chuck, it is drawn into a tapered hole in the headstock. This latter style is very commonly used on toolmakers' lathes.

BENCH LATHES

70. When small work must be finished with considerable accuracy, the ordinary engine lathe is too large and clumsy, and the hand lathe possesses neither the accuracy nor the attachments necessary for the work. Therefore, the bench lathe, or precision lathe, Fig. 46, may be used to finish this class of work. It is fitted with a double slide rest having automatic feed. The slide rest may be removed and other attachments substituted for special milling, grinding, or hand-tool and drilling operations. For cutting threads, a chaser bar is provided; this is operated like the one described in connection with turret monitor lathes. Special draw-in collets are used to hold small rods. These lathes, while not in reality watchmakers' lathes, resemble them. They are intended only for light work. The tailstock of the lathe shown in Fig. 46 has no set-over and provision for turning a taper is made by setting the top slide of the compound rest to the given angle of taper to be turned. A train of change gears on the head is provided for

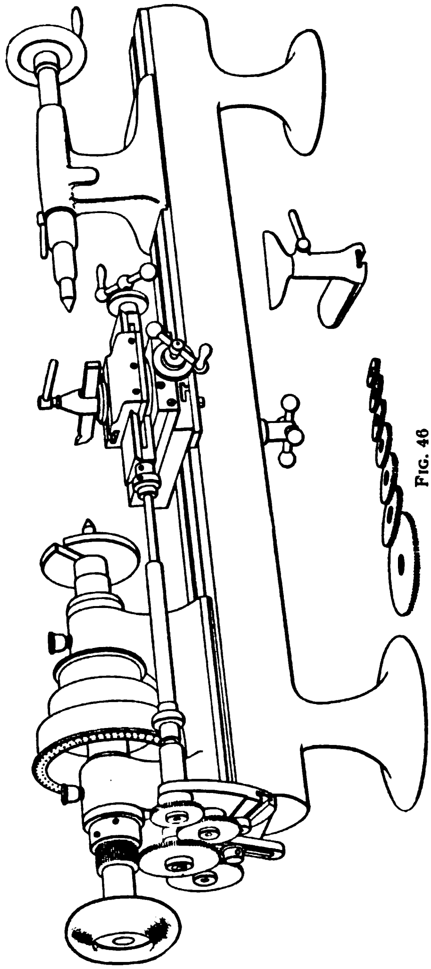


Fig. 46

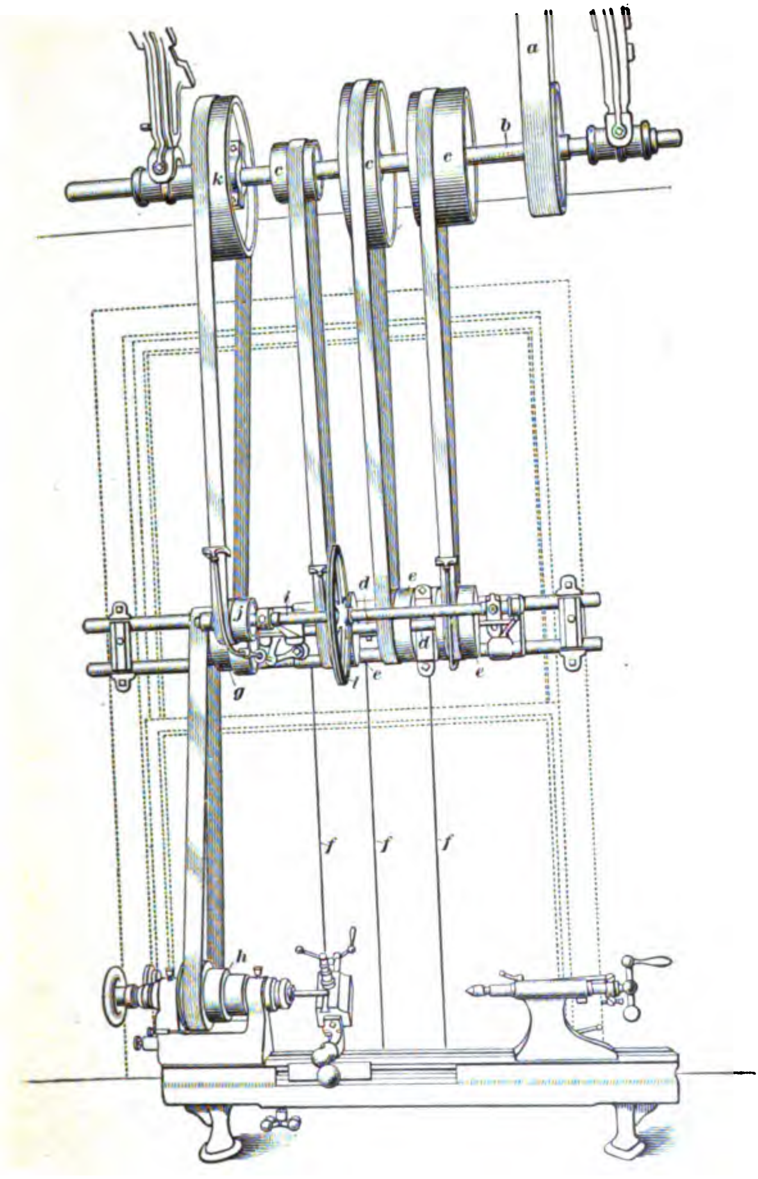


FIG. 47

feeding and thread cutting. The large cone-pulley flange is drilled with a number of index circles to be used for direct indexing, when cutting small gears or cutters or dividing circles. The spindle is held stationary during a cut by a pin that passes through a bracket on the head and enters any required hole in the selected index circle.

71. Driving.—The bench lathe should be secured firmly to a rigid bench facing a window where a good light can be had, as in Fig. 47. It is usually driven by a belt *a* from the main shaft to the jack-shaft *b*, which carries a number of pulleys *c* of different diameters to give the necessary countershaft speeds. A countershaft *d* is held in brackets on a frame secured to the wall midway between the lathe and the jack-shaft, and on it are a pair of tight and loose pulleys *e* corresponding to each driving pulley on the jack-shaft.

A shifter operated by a cord *f* is used to move each belt from the loose to the tight pulley to be used for any required countershaft speed. The countershaft also has a cone pulley *g* for varying the spindle speed of the lathe in connection with the cone *h*. A second shaft *i* is provided on the countershaft hanger and is driven through the pulley *j* by the large pulley *k* on the jack-shaft. The shaft *i* carries a grooved pulley *l* that is used to drive a grinding attachment clamped on the slide rest.

PLAIN TAPER-TURNING LATHE

72. A type of lathe used for both plain and taper turning is shown in Fig. 48. The lathe shown is made without back gears when it is to be used for light work; but is built with them if it is to be used for heavy roughing cuts. The headstock and the tailstock are carried on the **V**'s of a plate or secondary bed that is secured to the main bed by being so pivoted in the center that it may be set at an angle to the **V**'s of the main bed on which the carriage runs. The secondary bed is set by means of a scale at the end, in much the same manner as the guide bar of the taper attachment, and clamped in position by bolts shown under the bed at each end.

The advantage of this lathe is that the axes of the headstock and tailstock spindles are always in line, which prevents wear of the centers; also, any length of taper can be turned without resetting and there is no lost motion such as is sometimes found in the taper attachment.

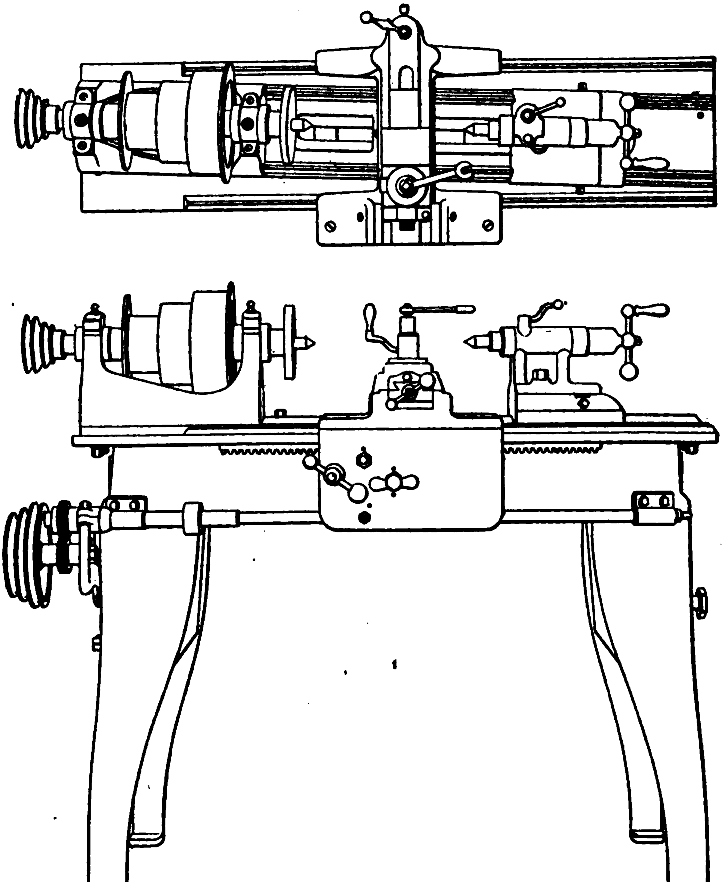


FIG. 48

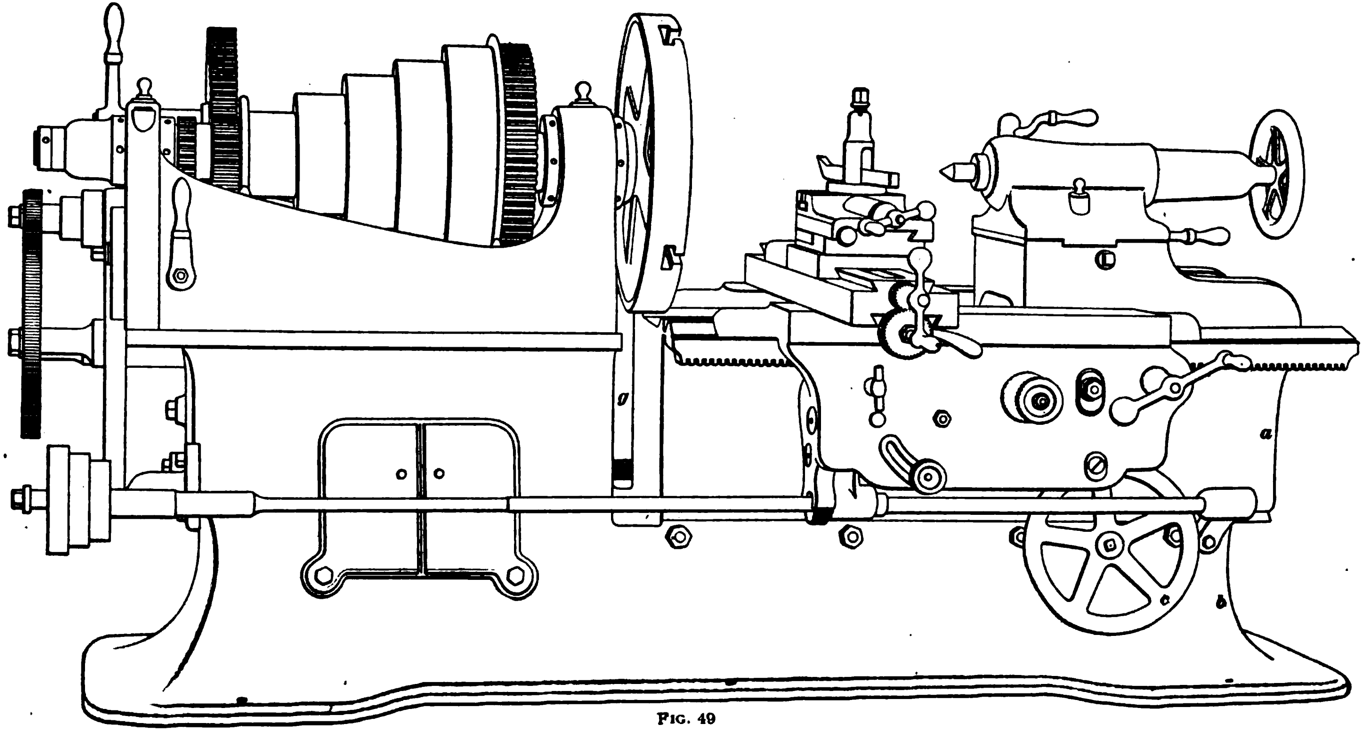


FIG. 49

GAP LATHE

73. A style of lathe often seen in shops where large lathes of considerable swing are seldom needed, is the gap lathe, shown in Fig. 49. Its principal feature is the second bed *a*, which slides on the main bed *b*. When ordinary work is to be turned, the top bed is moved up very close to the face plate, nearly closing the gap *g*. It is then used as an ordinary lathe. When a particularly large piece is to be turned, the upper bed is moved away from the headstock by turning the hand wheel *c*, thus opening the gap *g* and giving the lathe its full swing over the main bed *b*. The lead screw of this lathe is at the back and can be seen near the bottom of the gap.

TWO-SPINDLE LATHE

74. Distinguishing Features.—A lathe that in many shops answers for large and small work is the two-spindle lathe shown in Fig. 50. For ordinary work, the lower spindles *a* and *b* are used; but when the piece is too large to be swung on the lower set of spindles, the high ones *c* and *d* are employed and the tool post is blocked up by using a special cross-slide. The method of driving the upper spindle by a pinion on the lower

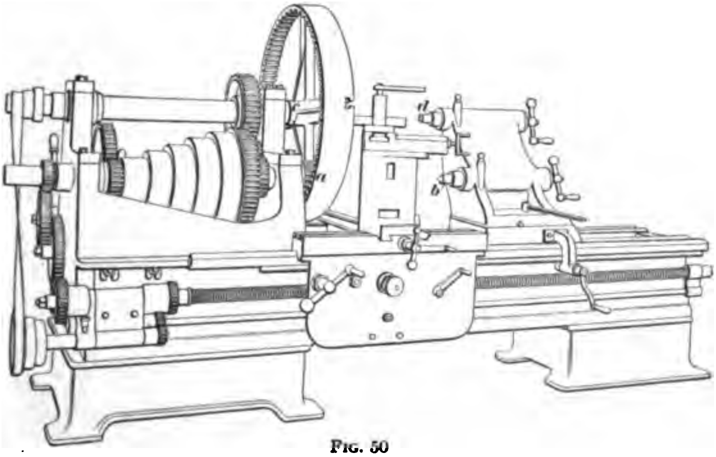


FIG. 50

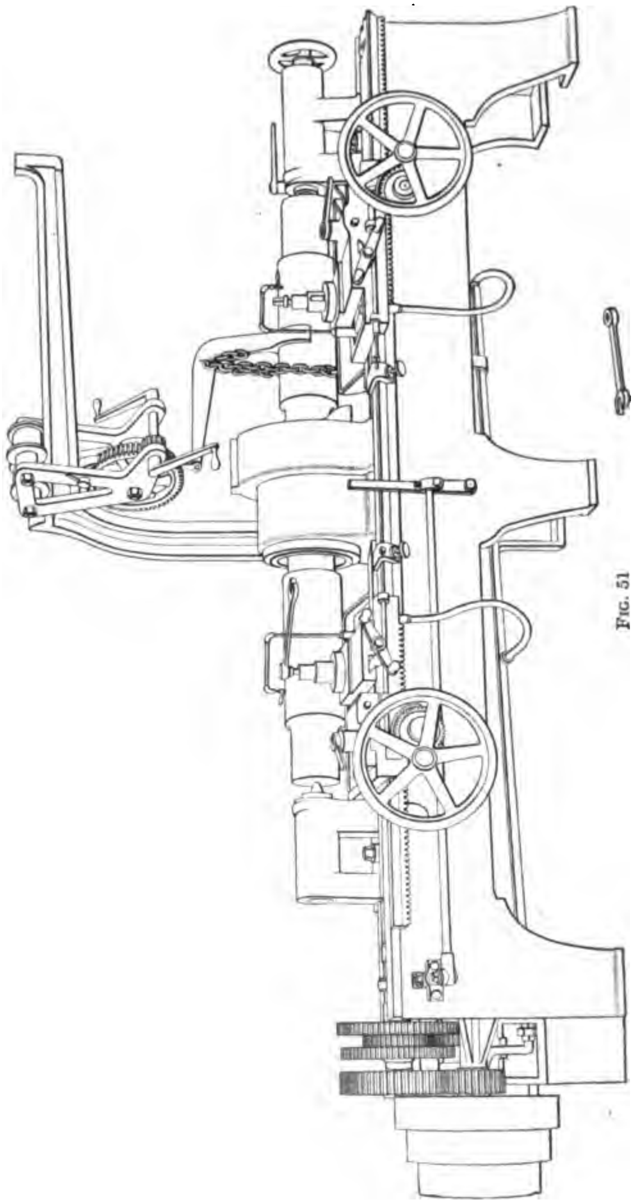


FIG. 51

spindle engaging the internal gear on the back of the face plate gives a powerful and steady movement to the work.

75. Blocking Up of Lathes.—It is common practice in lathe work, when the piece to be operated on is a little too large to be swung in the largest lathe, to block up the headstock and tailstock by putting under them wooden or iron blocks until the centers are sufficiently high above the bed to allow the work to swing. The gap lathes and the two-spindle lathes are intended to replace the blocked-up lathe. The lathes thus far mentioned have been of the same type as the standard engine lathe, with only slight modifications.

AXLE LATHE

76. Specially designed lathes are often made when there is enough of a particular kind of work to warrant them. Car axles may be turned on an ordinary engine lathe; but the work may be done much faster on one of special design, such as is shown in Fig. 51. This axle lathe is so designed that the two ends of the axle may be turned at the same time, which is accomplished by placing the driving head in the center of the lathe bed. This allows the work to be turned on dead centers, which is necessary when accuracy is desired; also, it leaves the ends free, so that a cut may be taken on each end at the same time. The driving head is operated by gearing connected by a shaft with the cone pulley seen at the left. The axle shown in place in the lathe is handled by the overhanging crane.

77. After the work is adjusted between the centers, the dog or driver is put in place. An equalizing dog or a two-tailed dog operated by an equalizing device should be employed, so that the force required to drive the work will not spring the axle. Chucks cannot be used, as they spring the work. Means are provided for keeping a large supply of soda water flowing on the tool during the cut. When the lathe is operated with high-speed steel tools it is of heavier construction and usually motor-driven.

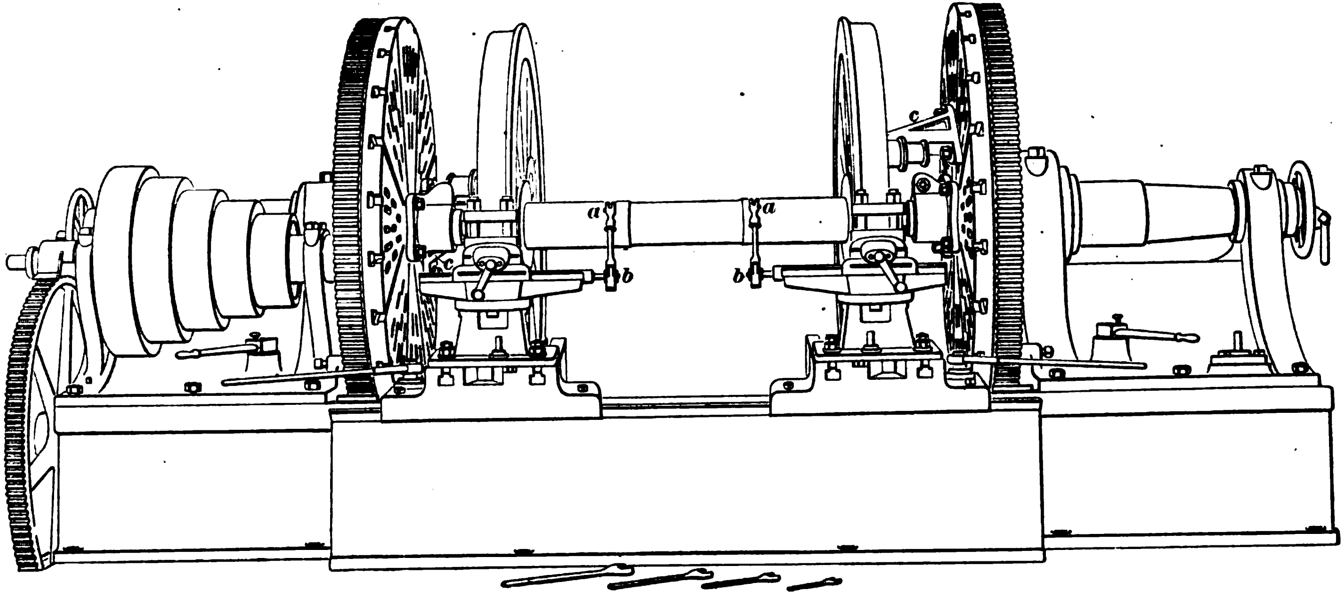


Fig. 52

WHEEL LATHE

78. A style of lathe especially designed for turning locomotive driving wheels after they have been pressed on to an axle is shown in Fig. 52. It is designed with two driving heads and two tool rests, thus enabling the operator to turn both driving wheels at the same time. There are no feed-rods along the bed to operate the tool carriages, as found in ordinary lathes. The tool carriage ordinarily used is similar to the compound rest, and it may be turned on its base and set at any angle. Two slides allow the tool to be moved in two directions, at right angles to each other. Screws for moving the slides are operated by a lever *a* connected to the feed-screws by ratchets *b*. These levers are moved automatically by levers and cams in a separate mechanism above the lathe, to which they are connected by chains.

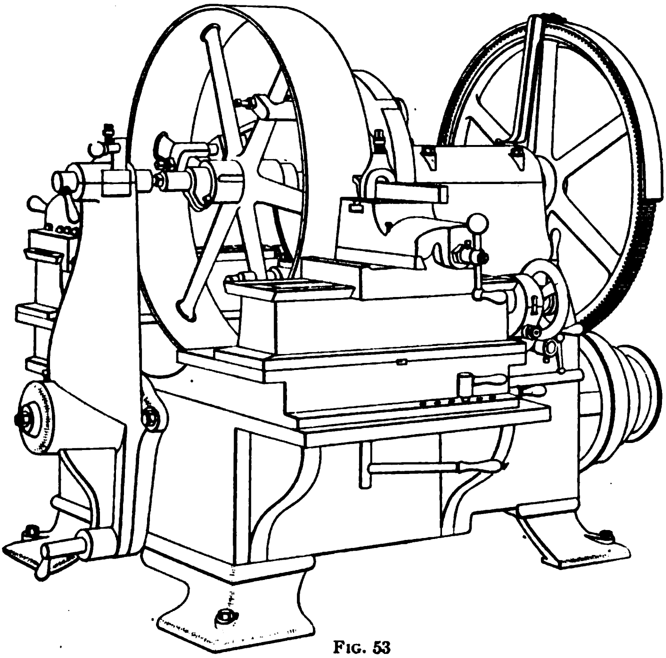


FIG. 53

79. After the wheels on the axles are put between the centers in Fig. 52, the drivers *c* shown on each face plate are so adjusted against each wheel that it is driven from its face plate. These lathes may also be used for boring the tires of locomotive driving wheels, the tires being bolted to the face plates and bored and faced, as in ordinary face-plate work. This method of boring tires is seldom employed, as they can be bored much better on a vertical boring mill. Driving-wheel lathes intended for the larger and heavier wheels are set so that the top of the bed is level with the floor, which allows the wheels to be rolled in and out without unnecessary hoisting. They are of very rigid construction and are usually driven by motors of such power that the lathes can be run up to the capacity of high-speed steel tools.

PULLEY LATHE

80. A type of lathe specially designed for turning pulleys is shown in Fig. 53. The lathe has two tool rests so that two tools may be used, one at the front and one at the back of the machine. Special driving dogs attached to the face plate drive the pulley by its arms.

HAND LATHE, OR SPEED LATHE

81. Description. Hand lathes or speed lathes are the smaller sizes of lathes used for drilling and such other operations as can be performed with tools held in the hand, or for operations that require a higher speed of work than can be obtained by the ordinary turning lathe. These lathes are without back

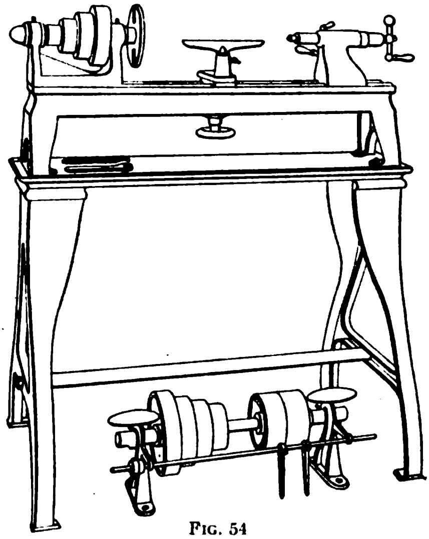


FIG. 54

gears or slide rests. Fig. 54 shows a standard type of hand lathe. It is mounted on a table, which makes a convenient place for holding tools and work.

82. Uses.—Work that is of irregular outline, requiring the use of hand tools, is often finished on the hand lathe. A small chuck fitted to the spindle of the lathe is very convenient for turning or pointing small rods and pins, and a variety of similar work. Drilling may also be done very readily on certain classes of work. When much drilling is to be done, a tailstock with a lever attachment for feeding the spindle is more convenient than the screw attachment. One of the principal uses for which the speed lathe is adapted is the polishing of cylindrical work. The various parts of a machine are polished to add to the attractiveness and to make the parts easier to handle and keep clean.

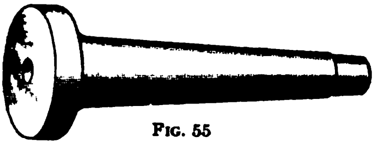


FIG. 55

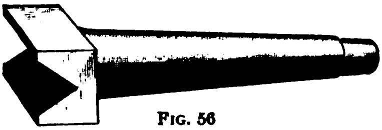


FIG. 56

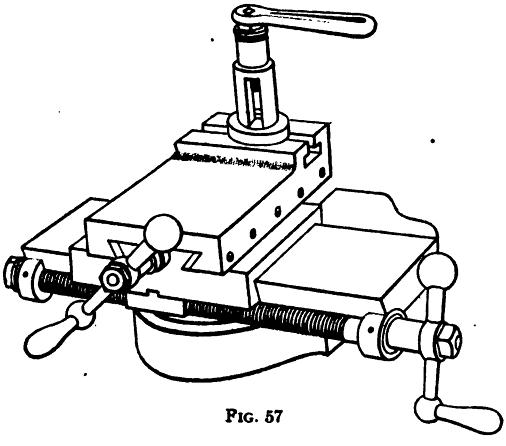


FIG. 57

83. Special Centers.—When the hand lathe is used for drilling or reaming center holes, the drill is held in a chuck and the work is fed against the drill by the tailstock spindle. If holes are to be drilled in thin flat pieces, a pad center, Fig. 55, can be used in place of the cone center. If holes are to be drilled diametrically through rods or tubes, a *forked center*, Fig. 56, aids in holding the work central.

84. Hand Slide Rest.—A hand slide rest that is often used on the hand lathe is shown in Fig. 57. The ordinary hand rest is removed and this one is clamped in its place. A small tool can be held in the tool post, and for light work it is very convenient.

85. Speed-Lathe Countershaft.—Machines like the speed lathe requiring but one direction of rotation of the spindle are driven by the tight-and-loose-pulley countershaft as shown under the lathe in Fig. 52. This consists of a shaft carried in two hangers. On the shaft is a cone pulley corresponding with the cone pulley on the machine and giving the required changes of speed. The countershaft is driven by a belt from the main shaft to one of the two equal pulleys on the countershaft. One pulley is secured by one or more setscrews, and the other is a loose running fit on the shaft. The belt is shifted from the tight to the loose pulley by the shifter and the belt guides. The shifter is carried in arms on the hangers.

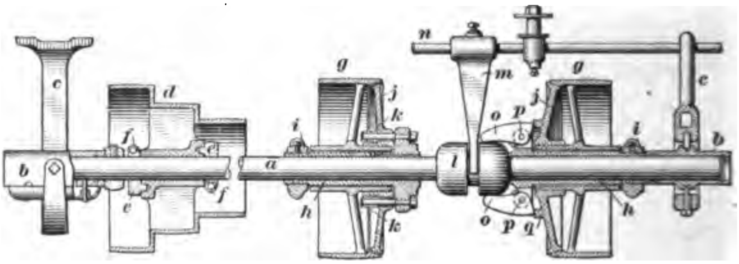


FIG. 58

86. Double-Clutch Countershaft.—Machines that must be run in both directions and that must be reversed more quickly than can be done with the two loose pulleys and one tight pulley are operated by a clutch countershaft, one form of which is shown in Fig. 58. The double-clutch countershaft *a* is held in two boxes *b* that are supported by the hooked lower parts of the hangers *c*. The cone pulley *d* is located at one end of the shaft, where it is held and locked by a split collar *e* at each end. The collars are of steel bored to fit the shaft and have lugs *f* on one side split for adjustment. They are clamped to the shaft by clamp screws. A projection on the side of each collar enters a hole drilled in the end of the hub and so locates and drives the cone. Some cone pulleys are held by setscrews. The two clutch pulleys *g* run on bushings *h* secured to the shaft *a* and are kept in place by the collars *i*. The inner ends of the hubs of the loose pulleys *g* are turned and carry the cones *j*, which are beveled at their outer edges to fit corresponding bevels on the pulleys. When the lathe is idle, these cones are out of contact with the pulleys *g* and the latter turn freely on their sleeves. The cones are held away from the pulleys by the pressure of the coiled springs *k*. Between the pulleys and free to slide along the shaft is a spool *l* that may be moved by the arm *m* attached to the shifting rod *n*. The sleeve *h* on which each pulley turns carries at its inner end two fingers *o*. When the spool is moved to the position shown, it spreads these fingers, which are pivoted on pins *p*, and the short outer ends of the fingers are thus pressed against the ring *q* that is part of the cone *j*. This pressure forces the cone into the pulley *g* and the two turn as one piece. Thus the motion of the pulley is communicated through the cone to the sleeve and to the shaft *a*, and thence through the cone *d* to the lathe. The pulleys *g* turn in opposite directions, so that by moving the spool to the other pulley the direction of motion is reversed. The two pulleys and their cone clutches are alike.

PIPE-CUTTING MACHINE

87. Construction.—A form of machine for cutting and threading pipes is shown in Fig. 59. The bed *a* is similar to a lathe bed and carries a headstock *b* that may be either cast with the bed or bolted to it. The headstock carries a large hollow spindle *c* fitted with three-jaw independent chucks *d* and *e* at

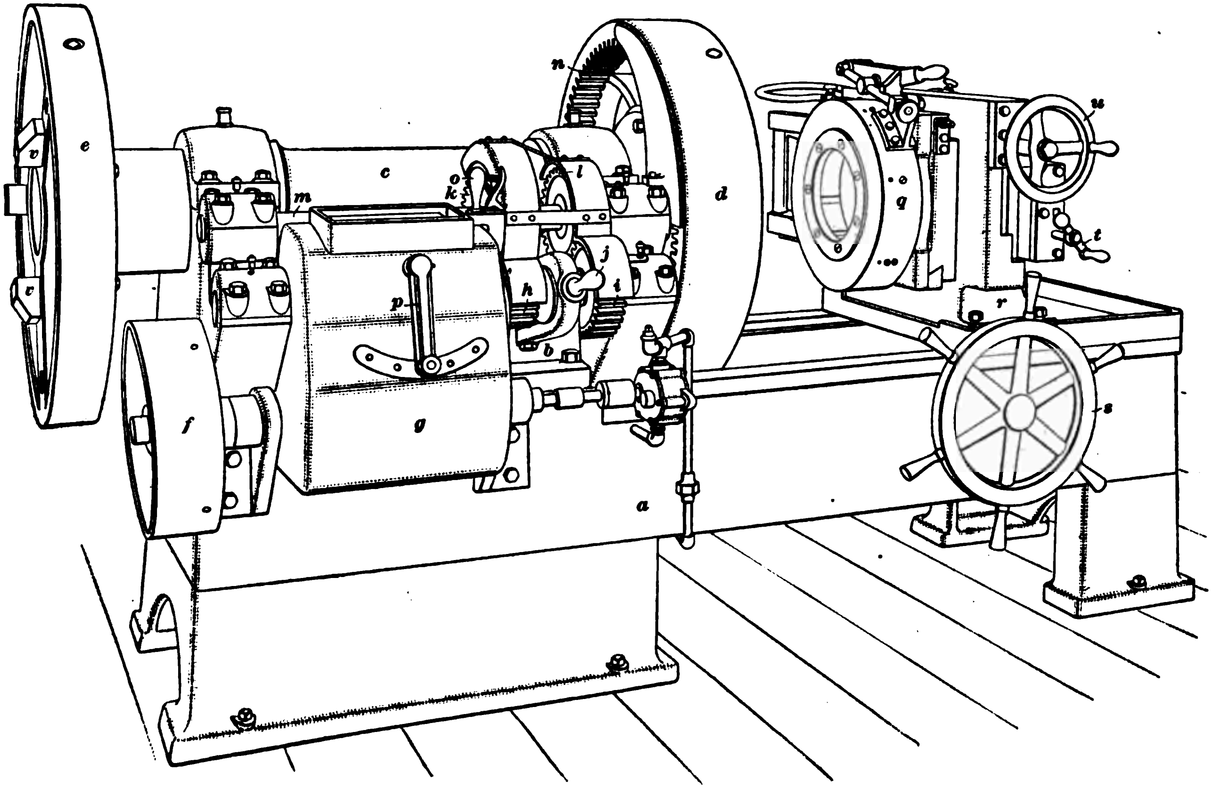


FIG. 59

the ends. The chuck *d* drives and centers the work, and the chuck *e* supports and centers it. The hole through the spindle determines the largest size of pipe that can be cut on any given machine. The driving belt of the machine runs on the pulley *f* and the required changes of speed are obtained by the use of the gear-box *g*. The two pinions *h* and *i* are driven by a shaft in the gear-box, and either may be made to turn with the shaft by the use of the clutch *j*. The pinions *h* and *i* mesh with the gears *k* and *l* on the shaft *m*, and a pinion on the end of this shaft drives the internal gear *n* on the chuck *d*. The gear-box contains a cone having five gears, and these run in oil, to avoid wear as much as possible. The two gears *h* and *k* are not of the same sizes as the gears *i* and *l*, so that five different speeds are obtained when each pair is used, or ten speed changes in all. The changes are made by shifting a sliding pinion in the gear-box by the levers *o* and *p*.

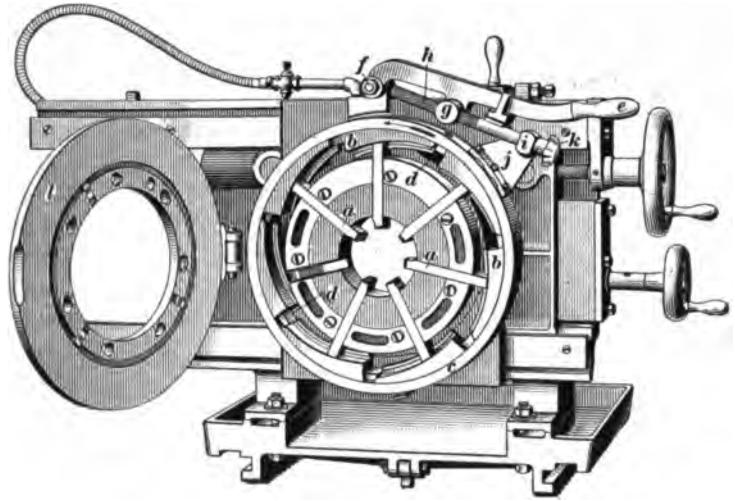


FIG. 60

88. The die head *q*, Fig. 59, is supported by a carriage *r* that may be moved lengthwise along the bed by racks and pinions operated by the capstan wheel *s*. The die head is carried by a cross-slide and when in use is free to center itself on the pipe in line with the axis of the spindle. When not in use, it may be moved back to the rear end of the cross-slide. It is moved back in this way when the pipe is to be cut off. The cutting-off operation is performed by a tool held in the cross-slide operated by the handle *t*. During this operation the pipe is steadied in a slide having adjustable jaws operated by the hand wheel *u*. The die head and the die with the cover swung back are shown in Fig. 60. The chasers *a* are shown in position in radial slots in the body of the die. At its outer end, each chaser has a lug or tongue that fits in a corresponding groove in one of the cams *b*. These cams are of hardened steel and are held firmly in place against the ring *c* by small wedges or keys *d* that are fastened to the ring by screws. One of these wedges and a screw are shown in Fig. 61 (*a*), and a chaser and a cam are shown in (*b*) and (*c*), respectively. The tongue *a* on the chaser fits down in the groove *b* in the cam, and the end *c* of the chaser bears against the face *d* of the cam.

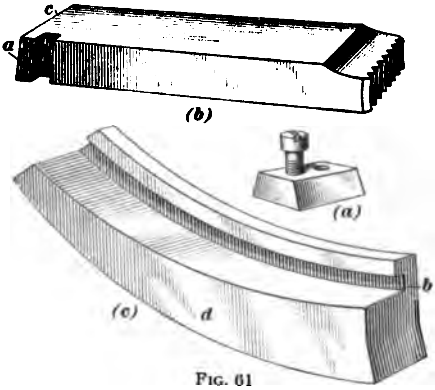


Fig. 61

89. The dies may be moved in or out, to adjust them to the size of the pipe, by the use of the lever *e*, Fig. 60. This lever is pivoted at *f* and at its middle is attached by a swinging joint *g* to a screw *h*. The screw is attached by a similar joint *i* to a bracket *j* bolted to the ring *c*. When the lever *e* is raised, the joint *g* is lifted and the screw in rising pulls on the bracket *j* and turns the ring *c* in the direction of the arrow, carrying the cams *b* in the same direction. As the tongue on each chaser *a* fits in an inclined groove in a cam, the movement of the cams in the direction indicated draws the chasers back, away from the center. When the lever *e* is forced down as far as it will go, as shown in the illustration, the ring is turned in the opposite direction and the chasers are pushed in. By turning the head *k* of the screw *h*, the length of the screw between the joints *g* and *i* may be altered, and the depth to which the chasers will cut is thus changed. The chasers are changed by swinging back the plate *l*, as shown, and removing them from their slots; or they can be removed through the center of the die head, without swinging back the cover. The slots are then cleaned and a new set of chasers are inserted. The number stamped on the side of each chaser must correspond with the number on the die body, beside the slot.

90. Threading Pipe.—Before being threaded, the pipe is cut to the specified length, using floor supports, if necessary, when the pipe extends some distance beyond the machine. The proper speed for the size of pipe and its material is given on a speed plate fixed on the front of the gear-box, and this plate also shows the gear and clutch to be used to obtain the desired speed. When the levers have been set, the machine is started, the die head is brought up to the pipe, and a liberal stream of oil is turned on the work and the die. The die head is now fed over the work by turning the capstan wheel. As soon as the die takes hold it begins to feed itself along the pipe. When it has cut to the correct length, usually so that the end of the pipe just comes through the chasers, the chasers are released and drawn back by raising the lever *e*, Fig. 60, and further cutting is stopped. The chasers should be set to cut to the proper depth by using standard blank gauges, so as to secure uniformity of threads for various sizes of fittings. On the rear chuck *e*, Fig. 59, are flange grips *v* for making up flanges. The flange is gripped in the chuck, the machine is reversed and the flange is screwed on the pipe, which is held on suitable supports.

91. Cutting Off Pipe.—A back view of the carriage and slide that support the die head is shown in Fig. 62. The die head *a* is moved out along the slide *b* to take it out of the way so as to allow the cutting-off tool *c* to be used. During the cutting-off operation the pipe is gripped and turned by the chuck *d*, one jaw of which is shown at *e*. It is steadied by the two **V**-shaped jaws *f*, which are held in slides and may be moved together or apart by turning the hand wheel *g* on the end of the right-and-left-hand screw *h*. The cutting-off tool *c* is fed forwards against the pipe by turning the hand wheel *i*, and oil is supplied through the pipe *j* by opening the cock *k*. After the pipe is cut off to the proper length, the die head *a* is moved back in position and the pipe is threaded, as already explained. A burr is left on the inside of the pipe after the cutting-off operation, and this may be removed by the reaming tool *l*, which is held in a short swinging bracket. When not in use, this tool is swung out of the way to the position shown, but when used to remove the burr, it is swung in toward the pipe, where it locks itself in position for its work. In the illustration, the chasers are open, as the handle *m* controlling the cam ring is raised.

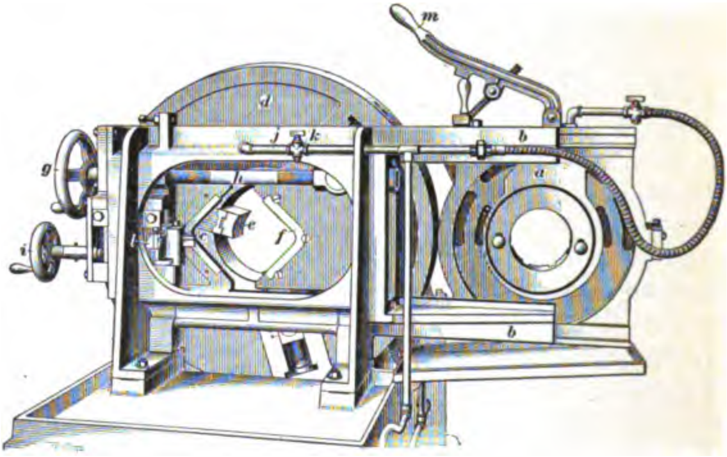


Fig. 62

BORING-MILL WORK

BORING MILLS AND THEIR OPERATION

CLASSES OF BORING MACHINES

1. Boring mills have been developed from the lathe and, in principle, are very similar to it. There are two types of boring mills, the *vertical* and the *horizontal*. Although these machines are known as boring mills, both are used for other operations.

The **vertical boring mill** may be thought of as a *face-plate lathe* so constructed that the spindle is vertical and the work, which is clamped to a table, revolves. The machine is adapted to turning as well as boring, and is often called a *boring and turning mill*.

The **horizontal boring mill** may be thought of as a lathe in which the work is clamped to the bed, and the cutting tool revolves, the tool being carried by a boring bar fitted to the spindle of the machine. Drilling and milling operations as well as boring may be performed on this machine, for which reason it is sometimes called the *horizontal boring, drilling, and milling machine*. Horizontal boring mills may be subdivided into the simple type of horizontal boring machine most commonly found in machine shops; the horizontal floor mill, used generally where large work is done; and special boring mills for cylinder boring and for boring spherical bearings.

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VERTICAL BORING-MILL WORK

2. Large Vertical Boring Mill.—In Fig. 1 is shown the type of vertical boring mill most used for medium and large work. The work is clamped on a rotating table *a* containing slots for T-head bolts, and the cutting tools are carried in the

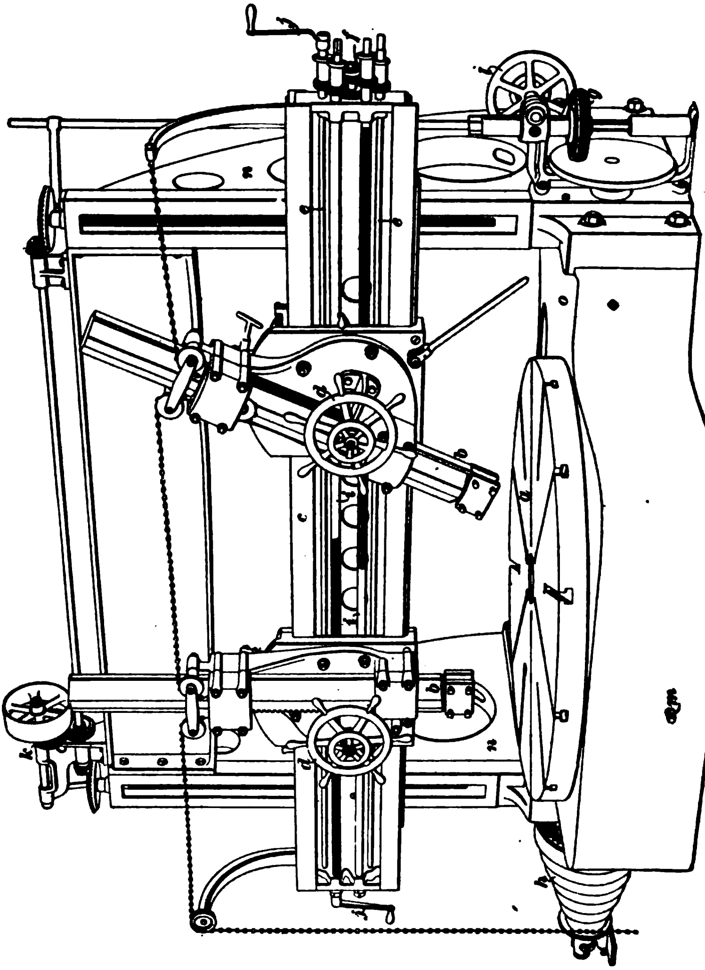


FIG. 1

lower ends of the boring bars *b*. The boring bars are carried in saddles, which travel on the cross-rail *c*. The tools are raised and lowered by means of the hand wheels *d*, or by power through the feed-rods *e*. These rods are geared to the boring bars, and connect by means of gearing at *f* and a friction wheel and disk at *g*, through the bed of the machine, to the driving cone *h*. The driving cone is driven by belt from an overhead countershaft. The tools are fed horizontally by means of the feed-screws *i*, which traverse the saddles on the cross-rail. The screws may be operated by hand by means of the handles *j*, or by power through the gearing at *f* and the friction wheel and disk at *g*. The cross-rail is raised and lowered by power through the pulley and gearing at *k*. This pulley is driven by belt from a separate countershaft. Instead of driving by belt, machines of this type are often driven by motors, one motor being used to operate the table, including the feeds, and another to operate the cross-rail.

3. The control of the feed is effected by the friction wheel and disk at *g*. The wheel can be raised and lowered by turning the hand wheel *l*; the position of the disk does not change. As the wheel approaches the outer edge of the disk it makes a greater number of revolutions at each revolution of the disk than it makes when near the center. When the friction wheel is carried below the center of the disk and moved towards the outer edge, the same range of speeds is maintained but the direction of motion is reversed. A great variety of both vertical and horizontal feeds in either direction is thus obtained, while clutches and reversing mechanisms in the saddles place the tool under the operator's control. Counterweights are provided in order that the various parts may be operated easily. Instead of the friction feed used on this machine, many boring mills are equipped with the gear-box feed described elsewhere.

4. The arrangement of the feeds is such that one tool may be turning the outside of a piece while the other is boring, or both may be either boring or turning on the same or different diameters, or one tool may be facing the top while the other may be either boring or turning. Conical turning or boring may be done by setting the head at an angle, as shown at the right hand in Fig. 1. When working on different diameters, the tool on the smaller diameter has a slower cutting speed than that cutting on the larger, and the speed must be adjusted for the larger diameter. These operations are virtually the same as those carried on in the lathe, and the tools used for these operations in the two machines are identical.

5. The table is rotated by means of an internal gear on its lower side, and a pinion that is connected through a pair of bevel gears to the driving cone *h*. A back gear like that on a lathe is provided, which, with the different steps on the cone, furnishes a wide range of speeds.

The table is supported in the center on a long vertical spindle running in a bearing near the top and another bearing at the bottom, while a step bearing at the lower end takes the thrust. The rim of the table runs in a groove in the bed, which is flooded with oil, and, when running slowly on heavy work, the greater part of the weight is taken on this rim.

Provision is made for raising and lowering the table when running at high speeds on light work, so that the entire load is taken by the spindle. A screw *m* connects with a wedge under the thrust bearing by means of a nut and lever, and, by turning the screw in one direction, the wedge is forced in, while rotation in the opposite direction withdraws it.

6. Extension Boring Mill.—In shops where there is occasionally a piece of large diameter to be turned, but where there is not enough very large work to warrant the purchase of a large boring mill, an extension boring mill may be used to advantage. On an extension mill, the bed *o*, Fig. 1, is made with an extension at the back and with ways on top, on which the housings *n* rest, and on which they may be moved back, so as to accommodate a larger piece on the table. The cross-rail is, of course, carried back with the housings, and, to do boring, it is necessary to use a vertical boring bar supported in an extension arm attached to the cross-rail or to place one of the heads taken from the cross-rail on the extension arm, which is not shown in the illustration. Holes may be bored by feeding the boring bar, which does not revolve, vertically; and the work may be turned and faced by feeding the head along the extension arm. When convenient, the boring bar may rest in the center of the table. This extension provision in a mill designed for the average work of a shop will enable larger pieces to be machined at a comparatively small increase of cost for machine tools.

7. **Attachments for Vertical Boring Mills.**—A **rail head** carrying a tool bar is often placed on one of the uprights of the machine. This head is conveniently located to undercut the outer surface and to turn the lower side of large work.

A **rear column,** carrying a tool head and bar, is sometimes attached to the back part of the bed. The rear column, like the rail head, is used to turn outer surfaces and to turn the lower side of large work. It may be used singly, but is generally used at the same time as the tool heads on the cross-rail. The rear column, rail head, and cross-rail heads may all be used at the same time.

8. **Small Vertical Boring Mill.**—A small vertical boring and turning mill is shown in Fig. 2. In principle, this machine is identical with the large machine previously described. It has, however, a turret head, a feed-gear box, and a fine feed adjustment, which devices are seldom found on the larger machines.

In the illustration, the feed-gear boxes *a*, by which the cross-feed screw and the feed-rod located in the cross-rail are driven, are shown on each side of the machine. By their use, any required feed may be obtained, the operation being similar to that of the feed-gear boxes used on lathes. The gears enclosed in them drive the feed-rods positively. They take the place of the wheel-and-disk friction drive shown in connection with the larger machine.

The machine has a swiveling head *b*, and a head *c* consisting of a five-sided turret in which boring and chucking tools are held.

9. The slots in the table *d* are so arranged that chuck jaws or jigs may be secured to the table. The work is then held in the chuck thus formed or in the jig when machining. A large variety of work that can be done on a lathe can be more conveniently done on a machine of this type. The mill is also much more rigid than the lathe.

To facilitate the fine feed adjustment, **capstan collars,** which are splined collars having holes in which a pin may be inserted to turn them, are used. When operating a machine equipped with capstan collars, the tools are moved approximately to their working positions in the usual way. To make the fine feed adjustment, the capstan collars *e*, which are free to slide on the feed-rod and screw and which are prevented from

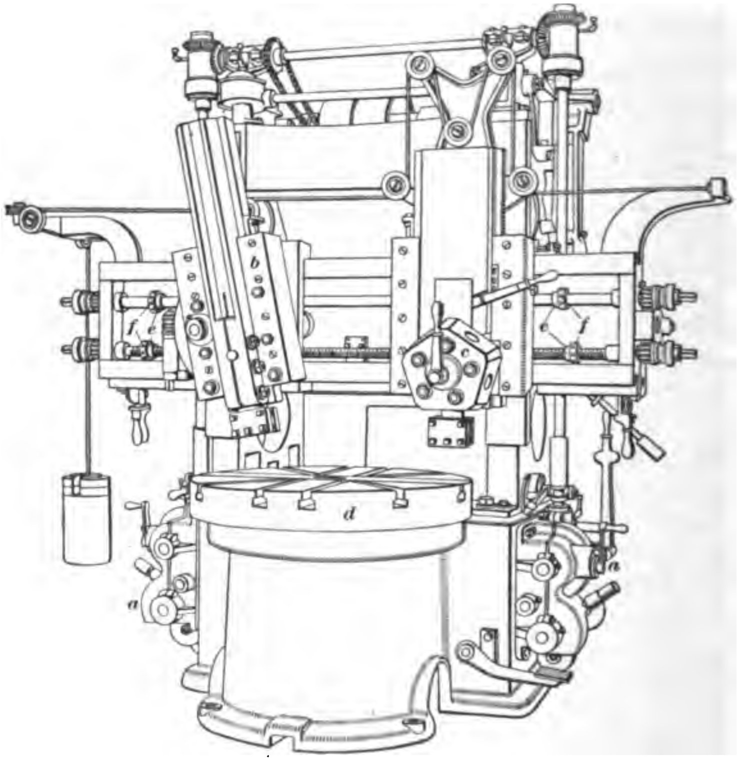


Fig. 2

turning by keys, are moved close to the tool heads. A short pin is inserted in one of the holes *f* of the collar and the rod or screw is turned the required amount. The advantage of the capstan collars is that they are more conveniently located to the operator than are the crank handles.

10. Setting Up Work on Vertical Boring Mill.—The horizontal table of the vertical boring mill makes the setting of work easier than in the lathe, as the piece can be placed loosely on the table and need not be secured while the settings and adjustments are being made. Small work is often held in a chuck similar to a lathe chuck, and large work is generally blocked up on parallel pieces and held by clamps, angle plates, and drivers, which are devices that prevent the work from turning on the table. Owing to the stiffness of the table, heavier cuts can usually be taken on the boring mill and more tools used at once than in a similar lathe operation.

The three following requirements may be taken as a guide when setting work. The piece must be set with the circumference to be finished exactly concentric with the center of rotation. In other words, it must be set so that it runs true enough to turn to size. The work must be set so that the center line, or axis, will be perpendicular to the top of the table. If the lower surface is irregular, the work must be blocked up to prevent springing and to bring the work level. The work must then be gripped with jaws, or clamped, as on the planer, with drivers to take the twisting strain due to the pressure of the cut. The drivers may be angle irons or plates or other braces to prevent the work from turning on the table while the cuts are taken.

11. Examples of Vertical Boring-Mill Work.—A plain piece of work such as an engine crank-disk, Fig. 3, for example, is held in the chuck jaws of the boring mill with the face *a* nearest the table, precisely as a piece of similar form would be held in a lathe face-plate chuck. The center *b* of the crank is then bored, the top *c* faced, and as much of the outside turned as the jaws will permit. The piece is next turned over, gripped in the jaws, and adjusted so that the turned and bored parts will run true. The face *a* and the unfinished part of the outside are now machined.

The center of the crankpin hole *d* is next accurately located at the correct distance from the crank center and a circle the size of the hole is drawn around it. The crank-disk is then set flat on the table enough out of center to bring the pin hole central. A pointer held in the tool holder is brought over the circle and the crank-disk adjusted until the circle follows the pointer. The disk is then securely clamped and enough weight added to the table to balance the crank and make the table run smoothly. The table is then speeded up and the small hole is bored to size.

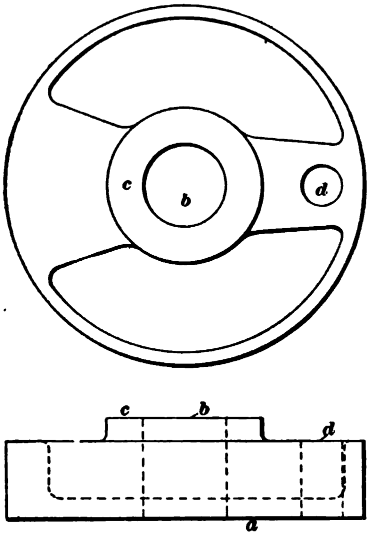


FIG. 3

12. Fig. 4 illustrates how an irregular piece may be secured on the table. Before setting a large piece, the table must be carefully cleaned and lowered so that the weight is taken on the outer rim of the bed as well as by the step bearing. When this is neglected, there is danger of injuring the step bearing and also of springing the table. The piece is then placed on the table, set approximately central, and leveled up by blocking at regular intervals. In Fig. 4, screw jacks *a* are used in leveling up. When the piece is approximately level, a small stick held lightly in the tool holder is brought very near the circumference or surface to be turned, and the table is rotated slowly. Careful observation of the distance between the part and the stick will show in which direction it must be moved to bring it perfectly central. The distance from the stick to the upper surface should be observed and the work adjusted until it sets level on the table. Several trials and adjustments are usually necessary before the work is correctly set so that all points pass at the same distance from the stick. The jaws *b*, which are supported on extension arms *c*, which in turn are bolted to the table *d*, are used for centering and clamping. The jaws are equipped with adjusting screws *e* to control the grip *f*.

13. When all adjustments have been made, two drivers, one on each side of the work, are set against any available projections. In the illustration, the drivers are the angles *g*.

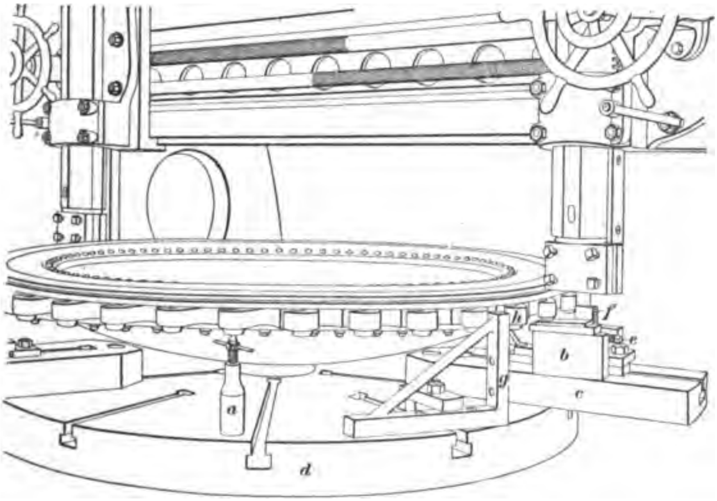


FIG. 4

They are set against the lugs *h* and clamped on the table, as shown. When the piece has been properly secured, it is well to test the setting again, and to look over all bolts, to be sure that every part is fastened securely, after which the machine may be started, the speed properly adjusted, and the tools fed as required. The shape of the tools, and the cutting speeds and feeds are the same as in a similar operation in a lathe.

The piece shown is held by three vertical jacks *a*, three jaws *b*, and two drivers *g*. On pieces where a flange or any other surface upon which a clamp may secure a hold is available, clamps are used in preference to the jaws, drivers being applied to prevent any sliding on the table. In some cases, the weight of the part, together with the clamps, furnishes grip enough on the surface of the table to prevent any slipping, but this grip is very uncertain, and it is better not to depend on it entirely.

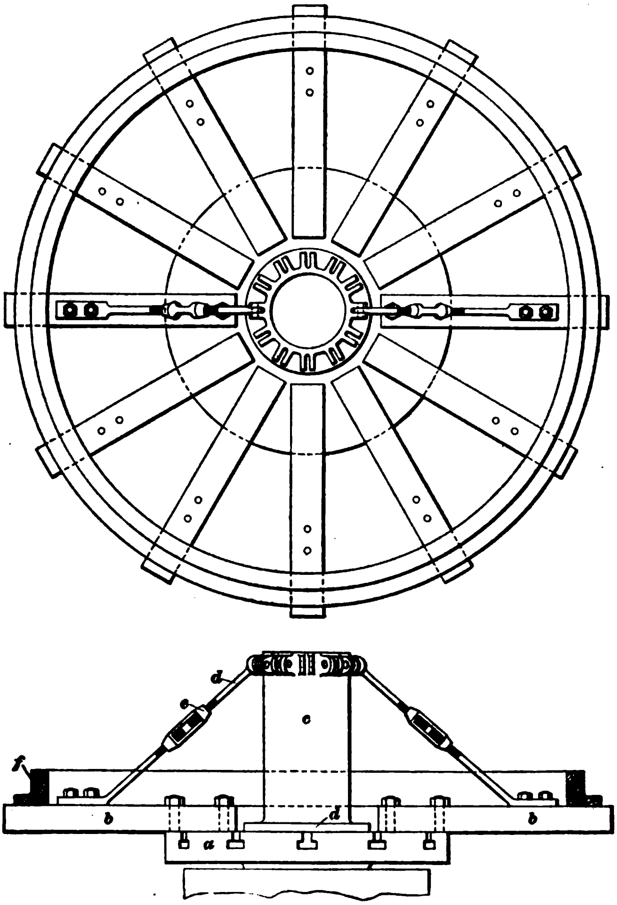


FIG. 5

14. Extension Arms for Vertical Boring-Mill Table. A boring mill is required at times to turn work that is larger in diameter than the boring-mill table. When this is the case, extension arms like those shown at *c*, Fig. 4 may be used. There are, however, cases where the extension arms must project so far beyond the edge of the table, and where the weight is concentrated so near the end, that additional support is needed to prevent objectionable springing. Fig. 5 suggests a means of providing such support when the center of the piece is open, as in the case shown. The table *a* of the boring mill is of the ordinary type, with radial slots. The extension arms *b* are bolted to the table in the ordinary way. At the center of the table a pillar *c*, with a flanged foot that is bolted to the table, furnishes the upper support for diagonal tie-rods *d* whose lower ends are bolted to the arms, thus forming an additional support. Turnbuckles *e* in the tie-rods permit the arms to be adjusted approximately level, after which a light surface cut may be taken to true them up perfectly. The work *f* is then fastened in any convenient way that its shape will permit, and turned to size.

This is a comparatively inexpensive and efficient shop expedient, which, however, may or may not be a means of economy, depending on the number of pieces for which it can be used and the cost of having the work done in a shop equipped for it. Shop expedients are frequently resorted to when the work could have been done outside more cheaply. Great caution should be exercised in their construction in order that true economy may be practiced.

15. Fixture for Turning Spherical Surface.—A fixture for turning a spherical surface on a vertical boring mill is shown in Fig. 6. The machine has two saddles. One saddle *a* has bolted to it a bracket *c*, which carries a pin *d*, around which swings the link *e*. The saddle *a* is clamped to the cross-rail so that the point *d* lies in a vertical line forming the axis of rotation of the table. The other saddle *b* is detached from the cross-feed screw in the cross-rail, and is free to move crosswise. A bracket *f*, having a roller on each end that bears on the cross-rail, is attached to the saddle so as to carry its weight, thus reducing the friction and providing a free motion along the rail. The boring bar *g* has an arm *h* attached near its upper end, which carries the fulcrum *i* of the link *e*. The link *e* continues to a point *j*, where a vertical link *k* is hinged. At the lower end, the vertical link *k* is hinged to the lever *l* at *m*.

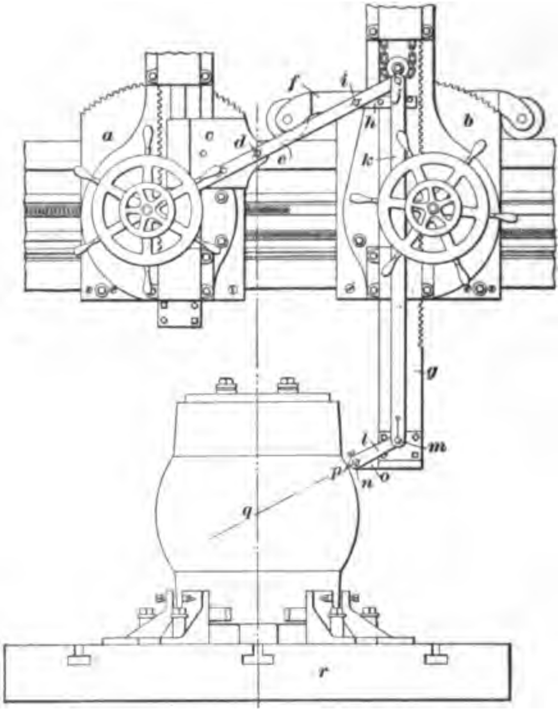


FIG. 6

The lever *l* is pivoted at *n* on an arm *o* attached to the bottom of the boring bar and at its end carries the cutting tool *p*.

16. The piece *q* to be turned is fastened centrally on the table *r* of the boring mill. When the links are properly proportioned the tool will travel in an arc of a circle, and, when the table is rotated and the boring bar is fed vertically, will turn in a true sphere. In order to accomplish this, the length of the link *k* and the vertical distance between the pivots *i* and *n* must both be equal to the vertical distance between the center of the sphere to be turned and the pivot *d;* the distance *d i* must be equal to the distance from the center of the sphere to the pivot *n*, that is, the sum of the radius of the sphere and the distance of the tool point from its pivot *n*, and the distance *i j* must be equal to the distance *n m*.

17. As the boring bar *g* is fed up, the saddle *b* will be drawn by the lever *e* toward the center of the sphere, when turning the upper half of it. The pin *i* then swings about its center *d*, and the pin *n* travels in an arc of the same radius about the center of the sphere. When in the course of the turning the pin *n* comes as near the table as the center of the sphere and the boring bar is fed downwards, the saddle *b* will again travel toward the center of rotation.

If the distance *d-i* is made equal to the sum of the required radius of the sphere and the distance from the tool point to the pivot *n*, the tool will form a perfect sphere of the required radius. The center line of the link *n m* will always point to the center of the sphere. In this work, a narrow, round-nosed tool is used with a comparatively light feed, so as to insure a smooth surface.

HORIZONTAL BORING-MILL WORK

18. Operations on Horizontal Boring Mill.—Horizontal drilling operations are so closely associated with horizontal boring that they will be considered together. Nearly all horizontal boring machines are designed for drilling, boring, and milling, the spindle being designed for any of these operations. As all holes to be bored must be previously drilled or cored, to form an opening through which the boring bar passes, an arrangement permitting the drilling and boring at one setting of the work is economical.

19. Small holes, up to about 2 inches in diameter, are usually drilled, and a machine that will do both the drilling and the boring with one setting saves a large amount of time.

Resetting, or moving to another machine, frequently takes more time and requires a larger number of men than the drilling or boring, and in the meantime the machine is standing idle and the additional service of a power crane is often necessary. For the same reason it is an advantage to be able to perform a milling operation at the same setting. These three operations require practically the same spindle action, and can, therefore, be carried on in the same machine. It is economy to have machine tools so arranged that the greatest possible amount of work may be done with one setting. This should always be borne in mind when selecting and arranging machines, as well as in their operation.

SIMPLE TYPE OF HORIZONTAL BORING MACHINE

20. Horizontal Boring-Machine Head.—One of the simplest types of horizontal boring machines is illustrated in Fig. 7. The general arrangement of the head resembles very closely that of a lathe, the cone pulley and back gears being the same. Instead of the ordinary face plate, there is an attachment on the end of the spindle for supporting either a drill or a boring bar. The spindle runs through the center of the cone and is so splined that, while it rotates with the driving gear, it may be fed through it by means of the screw *a*, which is turned either by the hand wheel *b* through the shaft and gearing shown or by power through the gearing at *c*.

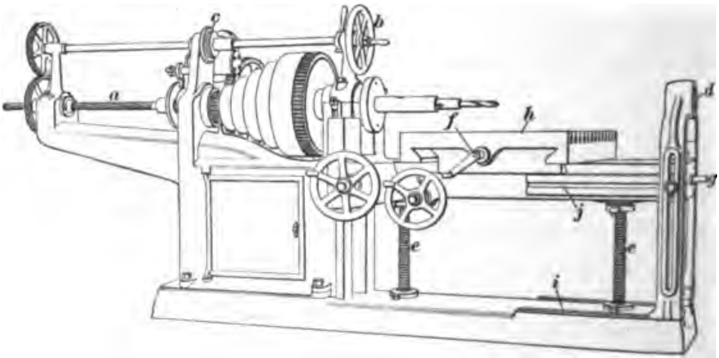


Fig. 7

21. Boring-Bar Support, Table, and Carriage.—An outer bearing *d* forms a support for the outer end of the boring bar. The table is also supported at the outer end and provision is made for vertical, side, and longitudinal adjustment by means of the screws *e*, *f*, and *g*, respectively. The screws *e* control the up-and-down movement of the table, and the screws *f* and *g* the crosswise and lengthwise movement of the cross-table, or **carriage,** *h*. In order to prevent any unnecessary spring in the boring bar, the yoke containing the outer bearing *d* may be moved near the work and clamped in position by bolts that fit in the T slots *i* of the base and *j* of the main table of the machine.

22. Boring.—Boring is done on a horizontal boring machine by supporting, independently of the piece to be bored, a bar that carries one or more cutters. The center of the bar thus forms the center of the bored hole independently of the center of the original hole. When the center of the new hole does not correspond with the center of the original hole, the heavy cut on one side will cause the bar to spring and the hole will be neither perfectly round nor straight. One or two light cuts after the roughing cut has been taken usually true it up. When the cut is uneven or when the hole must be bored very accurately, provision should be made for a finishing cut by using a roughing cutter set to bore a hole slightly undersize.

23. Single-End Boring Bars.—Four kinds of boring bars are used in horizontal boring mills, namely, *single-end bars*, *traveling bars*, *bars used on centers*, and *traveling-head bars*.

The holes in the work to be bored sometimes do not pass clear through the part to be bored and are known as *blind holes*. When this is the case it is, of course, impossible to support the boring bar on more than one end. The single-end bar shown in Fig. 8 (*a*) is used to bore blind holes. The shank *a* is tapered to fit the machine spindle and usually has a slot *b* through which a key may be driven to hold the bar in the spindle. The outer end of the bar is slotted, and a cutter *c* is secured in it by the setscrew *d*, which enters a drilled spot on the cutter. The friction between the shank and socket, the key, and the tang act as drivers. Single-end bars are generally made very short, so that they will be rigid. They are seldom used to remove more than a few inches of metal.

If holes must be bored very accurately, a set of cutters, consisting of one or two roughing cutters and a finishing cutter, is made. These are run through in succession to true and size the hole. If desired, the hole may be bored nearly to size and be finished by reaming. When cutters are made in sets they are always marked for the bar and slot in which they fit and are numbered in the order in which they are to be used.

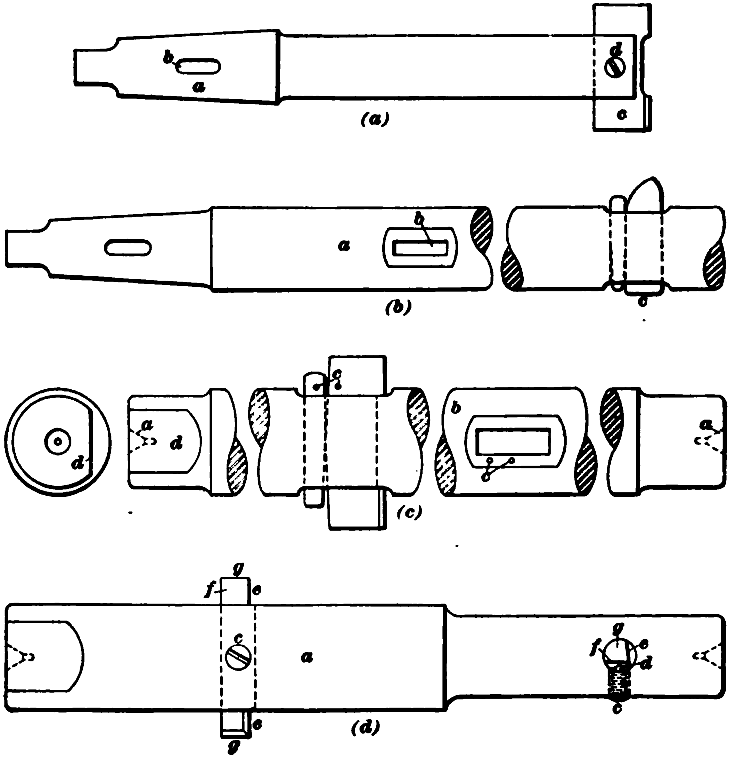


FIG. 8

24. Traveling Boring Bars.—Many of the horizontal boring mills depend for their feed on a spindle fed lengthwise through the head of the mill, and the boring bars used on them are known as traveling boring bars. The traveling boring bar shown in Fig. 8 (*b*) is made with a cylindrical body *a* having a number of slots *b* cut at various points in its length. Single-end and double-end cutters are keyed in the bar, as shown at *c*. When single-end cutters are used, they are adjusted to take a number of light cuts to true the hole. When double-end cutters are used, they are adjusted to cut on both ends. The traveling bar is held in the spindle by the taper shank and driving key and the tang. The outer end of the bar is supported by a closely fitting bushing in an outboard bearing. This bearing is carried on an upright support or in a yoke on the machine. The bar is turned straight, that is, to the same diameter throughout, so that it can feed freely through the supporting bearing, which is adjusted to the same height as the spindle axis, and in line with it.

Boring bars are frequently made with a slot near each end and one in the middle. These bars are usually made a little longer than twice the length of the part they are to bore. When boring with the cutter in the middle slot, the tool will then just clear the hole. The slots near the ends of the bar are used for facing, as there will be less tendency to chatter when the bars are supported close to the cutters.

25. Boring Bars Used on Centers.—When used on some types of boring mills, the boring bar is centered at the ends, as shown at *a* in Fig. 8 (*c*). In operation, it is driven by a lathe dog or a clamp. Single-end cutters held by a key are commonly used in boring bars. The double-end cutter, made to fit the bar, as shown at *b*, is also frequently used. The double-end cutters are trued in the bar by turning. Prick-punch marks *c* are then made on the boring bar, cutter, and key, as shown. When removed and replaced in position, the cutter and key are always inserted so that the prick-punch marks will be located in the same relative positions. A flat *d* is milled on the end of the bar to which the dog, or clamp, is attached.

When a boring bar is much smaller in diameter than the hole to be bored, a casting, known as a cutter head, slightly smaller than the hole is often secured on the middle of the bar. The tool is then secured to the side of the cutter head by clamps and capscrews.

26. A form of special boring bar used to bore two holes of different diameters but located in line is shown in Fig. 8 (*d*). This bar is made to be used on centers but may also be made with a tapered shank. The bar *a* is drilled as shown to receive the cutters, which are made of round tool steel and held in place by setscrews *c* that enter holes spotted in the drill point as shown at *d*. When the cutters are so spotted they will not slip when the setscrews are tightened. The cutters, when set, are turned to the required outside diameter and squared up on the cutting side as shown at *e*. Corresponding marks are then made on the cutters and bar, the cutters are removed, the face *f* is filed flat, and clearance is filed on the faces *e* and *g*.

Boring bars of this kind are generally used when a number of the same kind of pieces are to be bored. The cutters are run through in regular order, the first, or smaller, cutters taking the roughing and truing cuts; and the others, or larger cutters, taking the finishing cuts, which prepare the holes so that they may be finished by reaming. This type of bar could, of course, be made with rectangular slots as shown in Fig. 8 (*c*). In that case, the cutters would be secured in place by keys.

27. Traveling-Head Boring Bar.—The traveling-head boring bar, one form of which is shown in Fig. 9, is one in which the head holding the cutting tool is traversed along the boring bar. It is used to bore holes of comparatively large diameter, and is mounted on centers and driven by a dog or a clamp. A bar of this type is also well adapted to boring work secured to the ways of a lathe. The bar *a* is usually made of cast iron, cored out so as to furnish the greatest stiffness with the least weight. The traveling-head bar is made just enough longer than the length of the holes to be bored so that the boring head *b* will clear either end. The

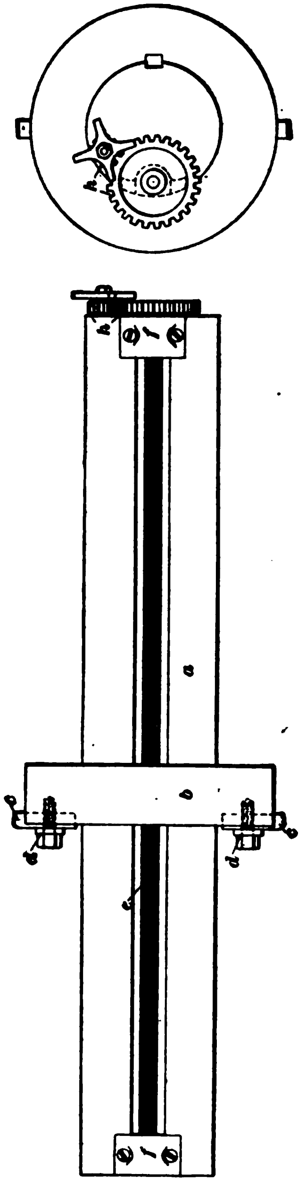
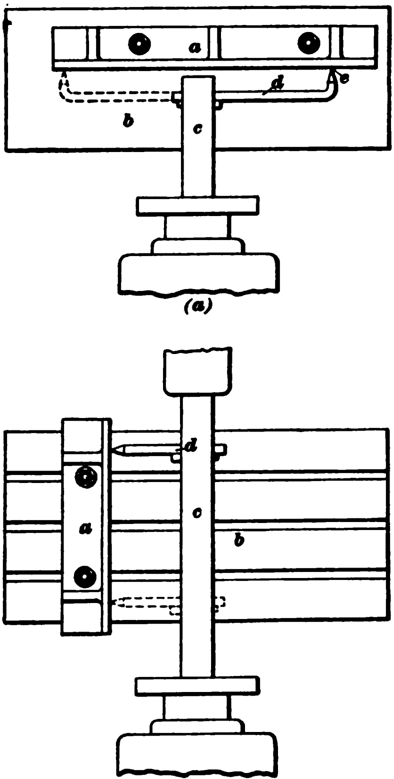


FIG. 9

head *b* is bored to fit the bar and turned on the outside to a diameter somewhat smaller than the diameter to be bored. One or more boring tools *c* are let into the head, as shown, and are held in place by the straps and tap bolts at *d*.

28. The boring head is traversed by means of a screw *e*, in a slot in the side of the bar, and a nut on the inside of the head. The slot is made large enough so that the nut is free to travel from end to end as the screw is rotated. The head is rotated with the bar by means of a key in the head and a spline that runs the entire length of the bar. The screw is supported at each end by the bearing *f* and is rotated with reference to the bar by means of a star feed that acts through the gears at *h*. As the bar revolves, each point of the star comes in contact in turn with a pin secured to a support that is attached to the machine in any convenient way, thus causing the rotation of the star. The movement of the star is transmitted to the boring head through the gears and screw as shown.

If a large boring head is used it is an advantage to use three or four roughing tools at different points in the circumference for light cuts. Several tools balance each other, and by their use the hole may be roughed out quickly, as the strain on each tool is much less than it would be on a single tool removing the same amount of metal. The finishing should be done with a single tool, as the bar will then spring less, and by taking a number of light cuts with a single tool a true hole will be produced.



(a)

(b)

FIG. 10

29. Setting Work and Tools.—The work, which is set on the cross-table, or carriage *h*, Fig. 7, can be drilled and bored in one position, then moved to another position and the operation repeated without resetting. The work is fastened on the table precisely as it is on a drilling machine, and care is taken to have the center line of the hole in perfect line with the center of the spindle.

30. Setting by Tramming.—The work, angle plates or other fixtures may be set square with the spindle by tramming. To do this, the work or fixture *a*, Fig. 10 (*a*), is first set on the table *b* approximately square with the boring bar *c*. A bent bar, rod, or wire *d* is then keyed in the boring bar so that its point *e* will project toward the surface to be squared. This surface and the tram point are then moved toward each other until a feeler such as a slip of paper is held lightly between them. The point of the tram is then moved up and down over the paper to determine the pressure. The boring bar is now turned half a revolution so that the tram is in the position shown by the dotted lines and the feeler is inserted between the tram point and the work. If the feeler is not held as at first, the work is adjusted according to the indications and another test made on each side. These adjustments and tests are continued until the feeler is held between the tram point and both sides of the surface with the same pressure.

31. Setting by Lining.—The operation of setting the work or the angle plate, or other fixture, parallel to the spindle of the mill is known as lining. An angle plate may be set parallel to the boring bar by adjusting the plate and measuring from the bar *c*, Fig. 10 (*b*), to the face of the angle plate *a*. One way to line the plate is to key a pointer *d* in the bar and move the table so that the end of the pointer will just come in contact with face of the plate as the bar is rotated back and forth. The pointer is then moved to the other end of the angle plate, as indicated by the dotted lines, by shifting the table *b* or by moving the spindle or bar endwise. The test is then repeated and the angle plate adjusted until the pointer touches the face with the same pressure at both ends. A feeler is best for testing the degree of contact between the pointer and the angle plate.

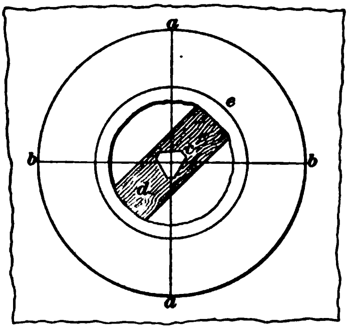


FIG. 11

32. Setting to Layout.—Work requiring one or more holes bored in it is laid out by drawing intersecting lines as *a a* and *b b*, Fig. 11, to locate the center of the hole or holes. The centers are located on the surface, if the stock is solid; but if it is cored the center is located on a triangular piece of tin *c* bent down at the corners and driven into a strip of wood *d* previously driven in the cored opening. The surface of the work is then chalked and from the center of the required hole a circle *e*, whose diameter is equal to that of the finished hole, is drawn on it.

The work is next secured against an angle plate or a parallel and the boring bar is put in position after the holes have been rough drilled, if not cored. The final adjustment is then made by securing a bent pointer *f*, Fig. 12, in the boring bar and bringing it nearly in contact with the surface of the work. The bar is slowly revolved and the distance the pointer is from the circle at various points is noted. Adjustments both vertical and horizontal are now made until the pointer follows the circle exactly. The pointer is then replaced by a cutter and the hole is bored, taking several cuts. It is well when near the finished size to note whether the bored hole is true with the circle. If it is not, a slight adjustment of the work may be necessary so the hole will be true with the circle.

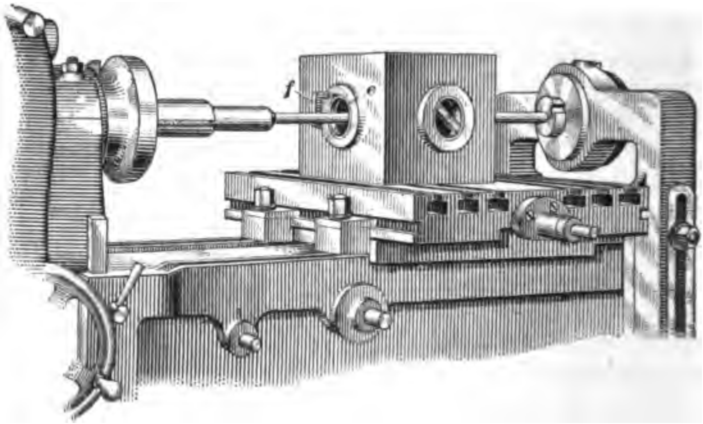


FIG. 12

33. Example of Vertical and Horizontal Adjustments.—It is frequently required to bore a group of holes at certain fixed distances from each other and from a center line. An example of boring work of this nature is shown in Fig. 13. Here, the work is set up to bore the top hole. The circles locating the holes are first laid out in the usual way. The top hole *a*, in this case, is bored first and the table is then raised the required amount to bore the lower holes, all the backlash in the elevating mechanism being taken up. If, however, the boring head were adjustable vertically, the lower holes would be bored first and the head would then be raised to bore the other holes. In this way, the backlash would be taken up.

34. When the top hole *a* is to be bored first, the work is lowered so that the center of the top hole is slightly below the center of the boring bar and then raised so that the height of the hole is the same as the measured or gauged distance of the boring-bar center above the table. The table is next fed crosswise to bring the bar central with the boring circle, and the hole is bored to size. The bar is then removed and the table raised the exact distance that the lower holes are to be below the upper ones. The cross-table is then fed crosswise the required distance, and, by taking up the backlash, adjusted to bore the hole *b*. After gauging and checking the distance the table is moved, the hole *b* is bored to size.

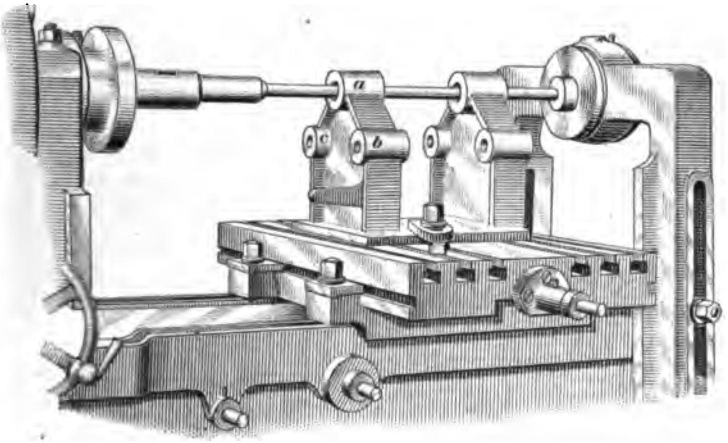


Fig. 13

The example in Fig. 13 shows another hole *c* on the other side of the center line. The setting for it may be made by feeding the table slightly beyond where it stood to bore the hole *b* and bringing it back to take up the backlash. The cross-table is then adjusted so that the cutter will just scrape in the hole *b*, after which the bar is removed and the table fed crosswise, the required center-to-center distance from the hole *b* to the hole *c*. To facilitate the adjustment of the boring-mill carriage, stops are often bolted to the side of it and the distances between them and the saddle are measured. If the cross-feed screw has a graduated dial, this adjustment may be made with it and checked by measuring or gauging. The hole is then bored and reamed. If there are other holes or groups of holes they are located and bored in a like manner.

35. Milling on Boring Mill.—The milling done in horizontal boring machines is similar to that done in the heavier types of milling machines. Solid cutters are used for the smaller work, and large inserted-tooth cutters, resembling the heads used on rotary planers, are usually employed in facing large surfaces. The horizontal boring machine is especially well adapted for facing irregular surfaces, the horizontal and vertical feeds being so arranged that either one or both may be thrown in at the same time, thus permitting any path within the range of the machine to be followed. The inserted-cutter end mill is probably the most used for milling on the boring mill, though other work such as dovetailing and **T** slotting are often done. The **T** slots are roughed out to the required depth with plain end mills and finished with regular **T**-slot cutters.

The single-end bar shown in Fig. 8 (*a*) is often used for dovetailing or undercutting, suitable inserted-tooth cutters being used.

HORIZONTAL FLOOR MILLS

36. Example of Horizontal Floor Mill.—A type of horizontal boring, drilling, and milling machine, known as a horizontal floor mill, that is used quite extensively in shops doing heavy work is illustrated in Fig. 14. The boring bar *a* and feed mechanism are carried in a head *b*, supported on a column *c*, which, in turn, rests on the bed *d*. The power is transmitted to the machine through the cone pulley and back gear at *e*, and is carried by means of shafting and gears to the boring bar. The machine is so constructed that the head may

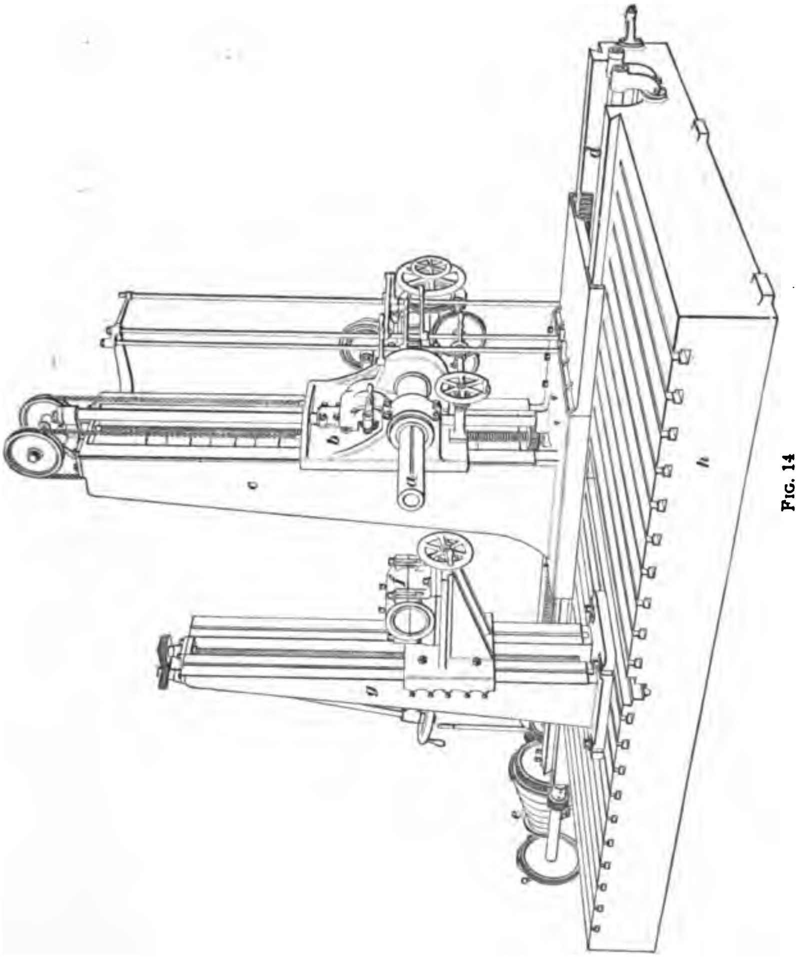


FIG. 14

be moved vertically on the column, and the column horizontally on the bed, while the boring bar moves in and out through the head.

The work is set on a floor plate *h*, which is provided with T slots, as shown. The outer end of the boring bar is supported in a bearing *f* mounted on the column *g*, which rests on the floor. The column and bearing may be moved to any location on the floor plate and adjusted to any desired height.

37. The floor plate of this type of machine is sometimes made very large, so as to accommodate very large work or more than one machine. A good arrangement consists of two machines set at right angles to each other, the one being of a heavy class designed principally for boring large diameters, while the other is somewhat lighter and is especially adapted for drilling and small boring operations.

38. Setting and Fastening Work.—The same principles used in securing the work on the tables of planers and vertical boring mills apply to horizontal boring mills as well. It is necessary to set the work perfectly level, and to line up the center line of the proposed hole with the center line of the boring bar. Parallels and blocks, or wedges, are used to raise the work a suitable height, and to level it up. Care should be taken to set the work so it cannot be sprung, and, when properly set, clamps are applied, as shown in Fig. 15.

39. Fig. 15 represents an engine bed set on a large floor plate and being operated on by a traveling-head boring bar driven by a large horizontal boring machine. The bed *a* is mounted on parallels *b*, near each end of the bed, which are clamped to the floor plate by means of the clamp *c*, and the bed is clamped to the parallels with the clamps *d*. A pair of pipe jacks *e*, running out from the corners, as shown, guards against both side and end motion. A duplicate set of parallels, clamps, and jacks, at the other end, which is not shown, holds the bed rigidly in place.

40. Arrangement of Boring Bar, Cutter, and Facing Head.—The illustration shows the boring bar *f*, the boring head *g* with two tools *h* in position, the traversing screw *i*, the outer bearing *j* with the front of its supporting column *k*, the facing head *l* with the tool *m* clamped on the tool slide *n*,

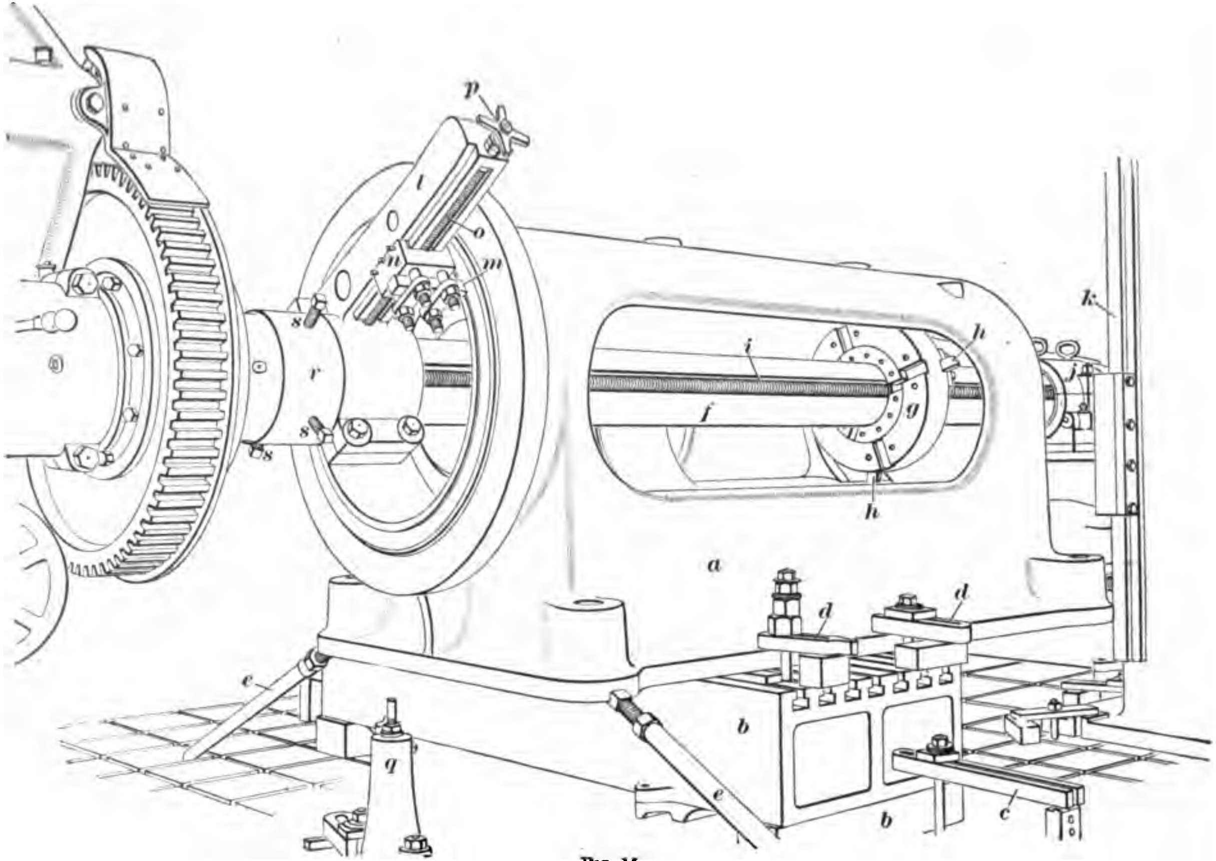


FIG. 15

the feed-screw *o*, the star *p*, and the star feed-post *q*, the last being bolted to the floor plate.

The boring bar is connected to the spindle by means of a special socket *r*. One end of the socket fits the spindle and the other end is bored out to receive the boring bar, which is gripped and held central by means of four setscrews *s*. The illustration shows a typical piece of work for this class of machine, and the usual method of supporting and holding it.

The work is faced true with the bore by the facing head, which is secured to the bar after the boring is done. The body of the facing head *l*, Fig. 15, can be attached to the boring bar at either end of the work by means of the cap and bolts shown, and the cutting tool will feed in or out, depending on whether the feed-post *q* is clamped on the right- or the left-hand side of the bar.

CYLINDER BORING

41. Setting Cylinders for Boring.—Engine, pump, or other cylinders in which a reciprocating piston must operate should always be bored in the position in which they are to be used. The cylinder of a vertical engine should be bored standing on its end, while the cylinder of a horizontal engine should be bored in a horizontal position. In large cylinders, especially, there is considerable spring due to their weight, which will tend to produce an oval shape when a cylinder that has been bored in a vertical position is laid on its side, or when a cylinder bored in a horizontal position is set on end. When the boring is done in its working position, this error is practically prevented.

42. Finishing Cut.—The working surface of the cylinder should be very carefully bored so that it will be cylindrical. There is some difference of opinion as to the best course to pursue to attain this end. Some persons claim that the finishing cut should be taken with a square-nosed tool so that the surface will be perfectly smooth; others prefer a rounded diamond point, the claim being made that the narrow point is less affected by unevenness in the structure of the metal, and that the slight ridges formed tend to reduce the amount of metal in actual contact, and are an advantage rather than a detriment. The slight ridges also tend to draw the oil under the piston, thus affording better lubricating conditions.

43. All shopmen agree that, whatever tool is used for the finishing cut, it should run continuously from one end of the cylinder to the other. The heating due to the action of the tool causes enough expansion that even a short stop will leave a noticeable ridge, and long stops make it necessary to bore the whole length over again. For this reason, cylinder-boring machines should be run by an independent engine or other motor.

44. Machines Employed in Cylinder Boring.—Cylinders are bored in lathes, vertical and horizontal boring mills, or special machines built for that purpose, depending on the amount of this class of work to be done. Except in shops where enough similar cylinders are bored to require one or more special boring mills, either an ordinary vertical or horizontal boring mill or a lathe is used.

45. Corliss Engine Cylinder-Boring Machine.—A machine for boring large Corliss engine cylinders is shown in Fig. 16. Two adjustable boring bars *a* and *b*, standing at right angles to the main spindle *c*, are provided for boring the ports, while the main spindle *c* bores the cylinder proper. An outboard bearing *d* for the main boring bar, which is mounted on a vertical slide on the column *e*, is raised and lowered by means of the wheel *f* to suit the spindle. The main spindle is driven through the cone and back gear at *g*, while the main head *h* is raised and lowered by a belt that runs on the pulleys *i* and moves the head with a vertical shaft through a worm and worm-gear at *j*. The small heads and boring bars *a* and *b* are operated through the cone and gearing at *k* and shafting and gears in the bed *l* and column *m*. The column *n*, with its bearings, forms an outer support for the two boring bars *a* and *b*. The cylinder is supported on the parallels *o* and *p*.

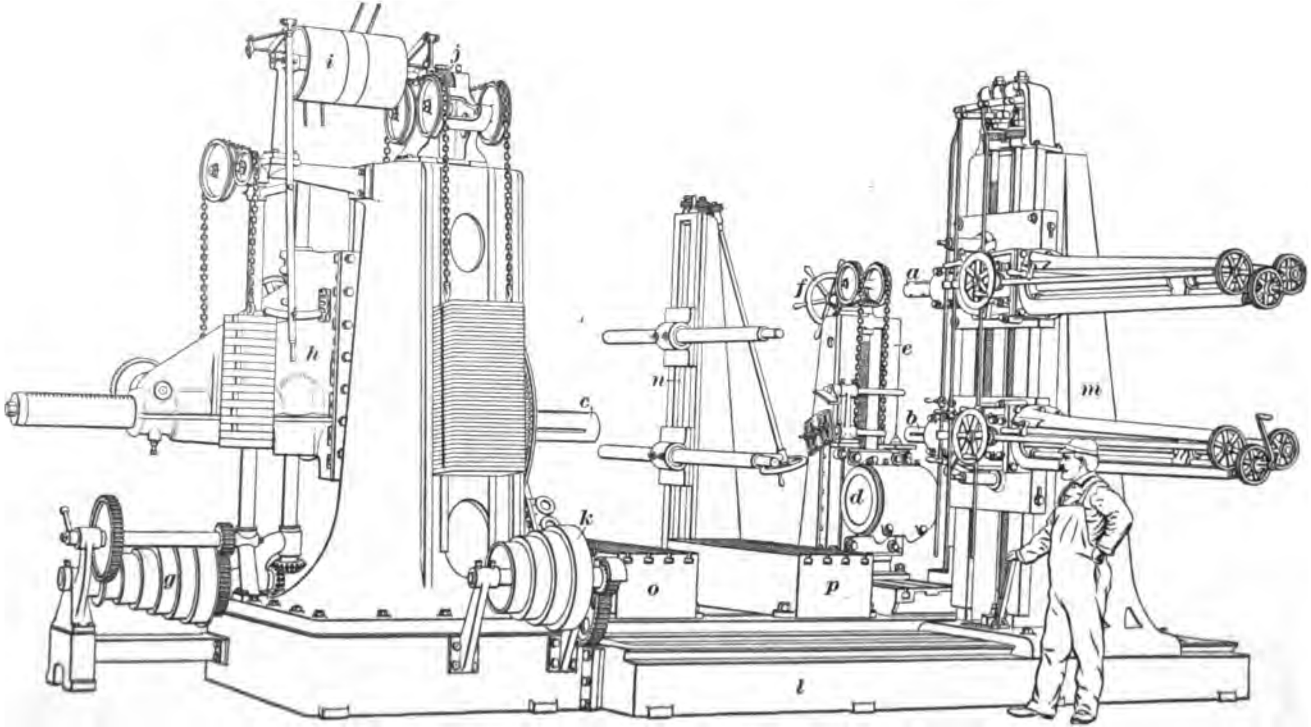


FIG. 16

46. Vertical Cylinder-Boring Machine.—In shops having a large amount of vertical cylinder boring to be done, special machines are sometimes employed; these machines are so constructed that the cylinder stands on a heavy floor plate, to which it is clamped. The boring is done by a vertical bar, the upper end of which, together with the driving mechanism, is carried by heavy columns. These machines are sometimes so constructed that the bar and a portion of the driving mechanism may be lifted out of the way while the cylinder is being placed in the machine. Such heavy machines are usually run by an independent engine or other motor.

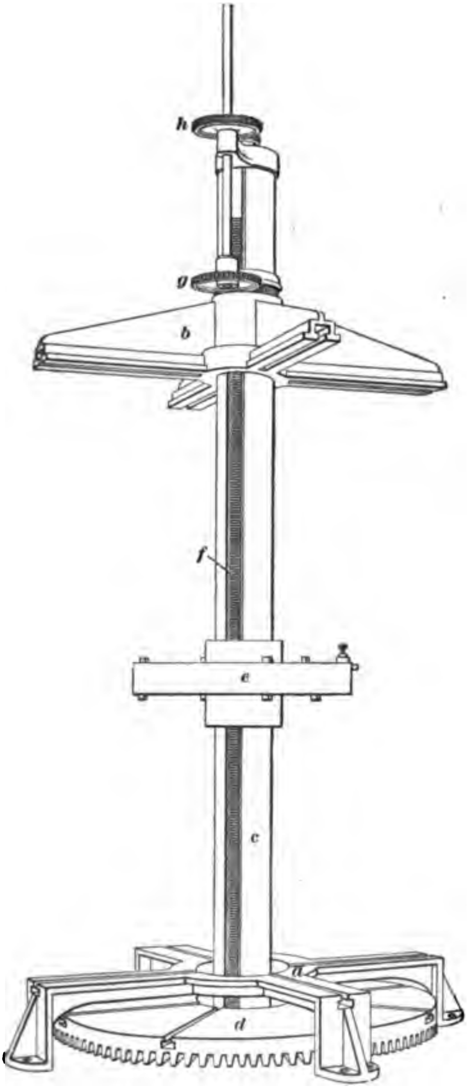


FIG. 17

47. Vertical Cylinder-Boring Bar. In shops where the work does not warrant the purchase of an expensive machine, a vertical boring bar, like the one shown in Fig. 17, may be used. The cylinder is supported on the stand *a*, and is clamped between it and the four-arm bracket *b* at the top, which also forms the guide for the boring bar *c*. The bar is rotated by a large bevel gear *d* and a bevel pinion driven by a shaft and pulley from which the machine receives its power. The cutter head *e* is fed by means of the ordinary feed-screw *f* and the reduction gearing *g* and *h* shown at the top of the bar.

BORING SPHERICAL BEARINGS

48. Boring Bar for Spherical Surfaces.—Fig. 18 illustrates a device used to bore internal spherical surfaces. It consists of a boring bar *a* having a double-end arm *b* pivoted on the axis *c*, which stands at right angles to the center line of the bar. The arm *b* carries on its outer ends two tools *d*, set in and clamped as shown.

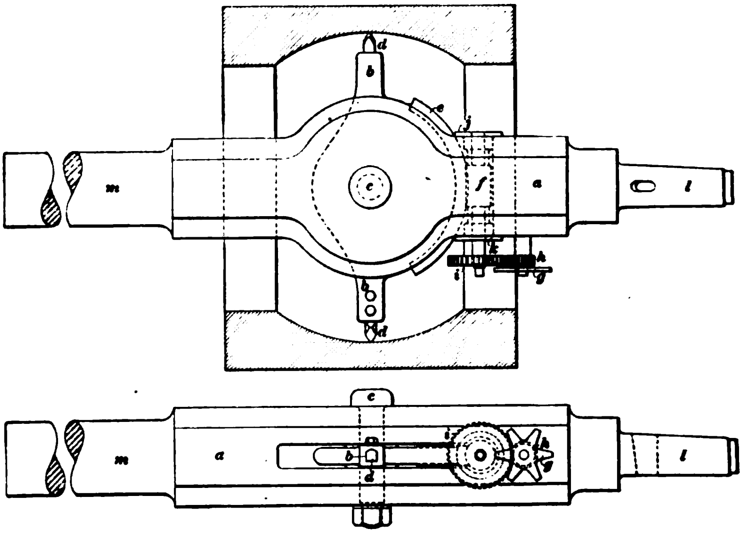


FIG. 18

If the arm *b* is turned about its axis *c* while the bar *a* is rotating, the tool points will bore an internal spherical surface. In order to secure this motion, the arm *b* is constructed with the segment *e* of a worm-gear on one side. A worm *f* engages with this worm-gear, so that when the worm is rotated, the arm swings about the center *c*, causing the tool points to travel in an arc about the same center. The worm *f* is revolved by a star *g* through the gears *h* and *i*. A post on the floor operates the star in the usual way. The worm *f* is supported in two flanged bushings *j* and *k*, while the arm *b* is pivoted on a through bolt. The end *l* of the boring bar is made to fit the spindle of a large horizontal boring mill in which it is used, while the end *m* fits the outer bearing. Narrow round-nosed tools are usually employed with a fine feed, so as to form a smooth surface. For the roughing cuts, the two tools may be used, but for the finishing cut, it is best to use one tool only.

49. Portable Device for Boring Spherical Surfaces. When the amount of spherical boring to be done does not

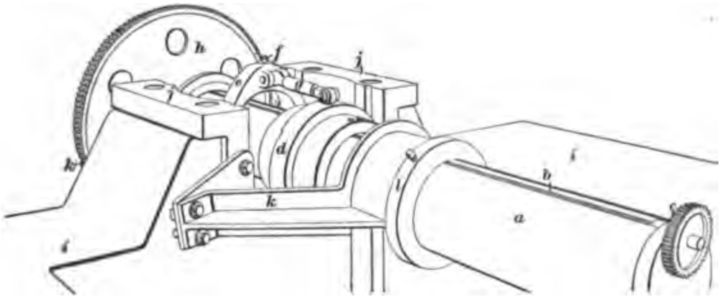


FIG. 19

warrant the construction of a bar as illustrated in Fig. 18, or in cases where a portable arrangement is necessary, a boring bar may be fitted up as shown in Fig. 19. An ordinary boring bar *a*, with its feed-screw and gearing *b* and *c*, and boring head *d*, is fitted up with a forked arm *e*, which is pivoted on both sides of the bar, so that the axis of rotation of the arm and the center line of the bar intersect at right angles. The arm *e* carries a tool *f* and is connected with the head *d* by the link *g*. The boring bar is rotated by means of the worm-gear *h* and a worm and pulley that are not shown. As the screw *b* is rotated, the head *d* is moved along the bar, and the link *g* causes the arm *e* to swing about its axis, and, when both bar and screw are rotated, the tool will form the desired spherical surface.

The illustration shows the bar mounted on a large engine bed *i*, ready to bore the spherical bearing *j*. The bar is supported on two brackets *k* bolted to the ends of the bearings, and is kept from moving endwise by means of the worm-gear *h* on one end and the collar *l* on the other end.

BORING FIXTURES

50. Fixture for Boring Duplex Pump Cylinders. Fig. 20 shows a fixture for holding a set of four pump cylinders while they are being bored in a double-head machine, which is also double-ended, the four cylinders being bored at the same time. The cutters at the two ends of the machine rotate in opposite directions, thus lessening the tendency to move. In Fig. 20, *a* shows the device empty, while *b* shows a pair of cylinders mounted in the machine. The cylinders rest on a pair of cross-bars *c* supported on four adjusting

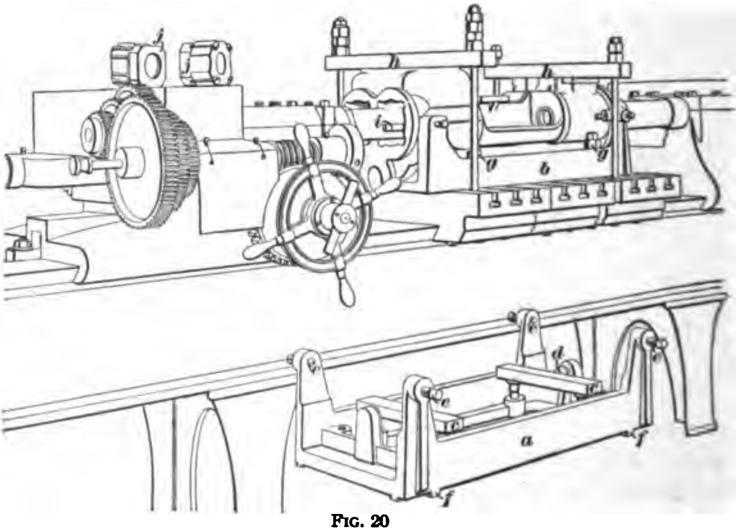


FIG. 20

screws. The end adjustment is made by means of a screw *d* at each end, only one of which is seen, while the side adjustment is made by means of the four screws *e*.

51. The fixture is set on the table, as shown, the two tongues *f*, Fig. 20, fitting into corresponding slots, to prevent any slipping and to insure perfect alinement on the table. The fixture is clamped on the table by means of the bolts *g*. When the cylinders are in place and the adjusting screws are set up tightly the cylinders are held securely by means of the clamps *h*. The illustration shows a roughing cutter *i* just entering the cylinder and a pair of finishing cutters *j* lying on the top of the machine.

52. Special Boring Fixture.—Fig. 21 illustrates a special fixture that may be used on either a boring mill or a lathe, for boring the connecting-rod pin hole of a gas-engine piston. The piston *a* is held between the two **V**-shaped castings *b* and *c*. The casting *c* is bolted firmly against the side of the rest as shown, and the casting *b* is loose. The piston is placed between the **V**'s, and, when set in its correct position, *b* is drawn up against it by the two end bolts *d*, and the clamping bolts *e* are tightened. In the illustration only one of the bolts *d* and *e* are seen, the others being located in the rear. The boring bar *f* is then passed through the **V**'s and the piston, and the holes are bored in the usual way.

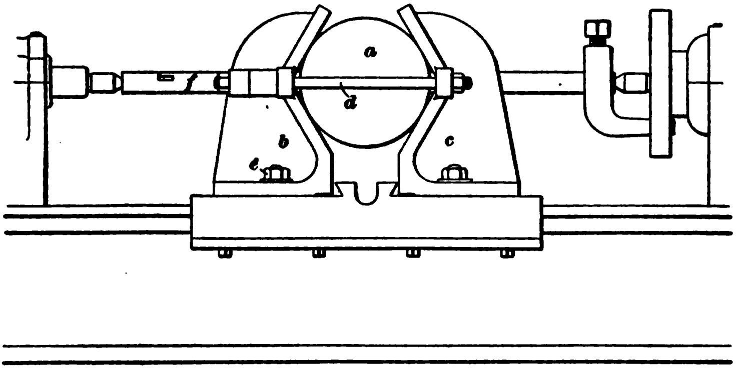


FIG. 21

This arrangement insures a hole that is perfectly central and square with the piston. For larger pistons, a single **V** is used in a larger machine, the piston being simply clamped against it.

53. Boring on Drill Press or Radial Drill.—Light boring work that is ordinarily done on a boring mill or lathe may be done on a drill press or radial drill when a suitable jig is provided to support the ends of the boring bar.

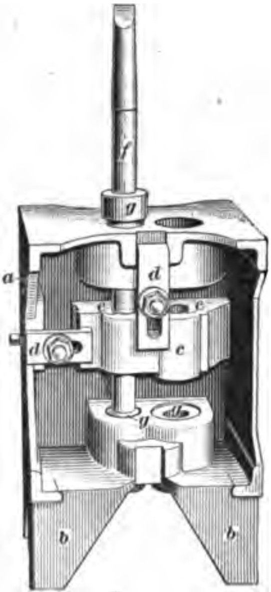


FIG. 22

A good example of a boring jig that may be used on a drill press is shown in Fig. 22. The jig is of the box type and the body *a* is supported by the four feet *b*. The work *c* to be bored is secured to the jig body by means of the two clamps *d*. Two cored holes *e* are to be bored. The boring bar *f* is guided by hardened steel bushings *g* in the upper and lower ends of the jig. The machining operation is as follows: The work is clamped in position against the stops and the boring bar is inserted and fastened in the spindle; one or more double-end cutters are then fed through the cored holes, after which the hole may be reamed with a finishing reamer. The same process is repeated for the other hole.

54. Hand-Power Boring Fixture.—It is frequently necessary to bore or true holes in work that it is impossible to put in a boring mill. This occurs when no boring mill is available, or when a machine bearing gets cut and the expense of taking the injured part out would be too great; it occurs also in repair work, when the boring must be done away from a shop.

A satisfactory hole may be bored by making or selecting a suitable boring bar and providing two bearings in which the bar is an easy sliding fit. The bearings are then mounted in line with the hole to be bored. The bar is now passed through the work and the bearings carefully leveled and squared so that the hole to be bored will be in the required position. The adjustment of the bar requires skill and judgment. The bar must usually be so adjusted that the hole will have a fixed relation to the other parts of the machine.

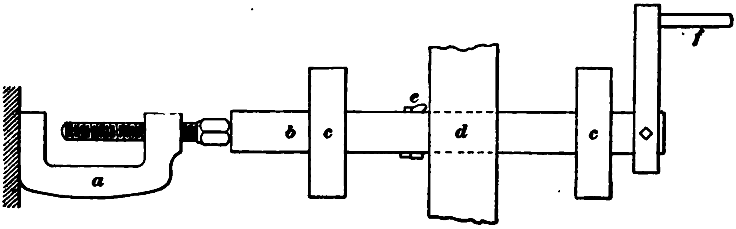


FIG. 23

It is sometimes necessary to take down adjoining parts to uncover flat surfaces or to clear holes from which the boring bar may be located by tramming or lining. A screw clamp *a*, Fig. 23, may be secured so that its screw can be used to feed the bar *b* through the bearings *c* and the work *d*. A cutter *e* is held in the bar, which is rotated by turning the crank *f* by hand.

WORKING CHILLED IRON

CHILLED IRON

1. Chilled iron is cast iron that has been chilled, or cooled, rapidly as the molten metal is poured into a mold. Chilling is accomplished by using an iron mold instead of a sand mold, as in ordinary molding. This iron mold is called the **chill**, and, like the sand mold, must have the correct form to make the desired casting. Not all forms of castings may be chilled, owing in some cases, to the severe casting and shrinkage stresses, and in other cases to the inability to chill inaccessible parts of the casting.

In Fig. 1 is shown a cross-section of a mold for making a plain, solid, chilled-iron roll with necks and driving ends, the body only being chilled. The mold for the necks and driving ends of the roll is made of sand. In the illustration *a* is the roll, *b* the chill, *c* the riser head, *d* the cope, *e* the reducer, *f* the sand, *g* the drag, *h* the runner spout, *i* the pouring basin, *j* the joints fastened by clamps and wedges, *k* the end plate, and *l* the chilled surface.

2. Characteristic Features.—The rapid cooling of the metal which lies against the chill forms a skin or shell of hard iron varying in depth and hardness according to the composition of the metal and the method of manufacture. This rapid cooling of the metal produces a casting with a hard surface having a great resistance to wear.

Chilled iron may readily be distinguished from sand, or gray, iron by the white color of the fracture as opposed to the gray color of ordinary cast iron. The outer, or clear white, layer

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is known as the **clear chill.** Where the shell of chilled iron merges into the gray iron will be found a layer of **mottled chill,** which is a mixture of chilled and gray iron. The mottled-chill layer is usually of about the same depth as the clear chill, the remaining part of the casting being gray iron. The layer of clear chill plus the layer of mottled chill is known as the **total chill.**

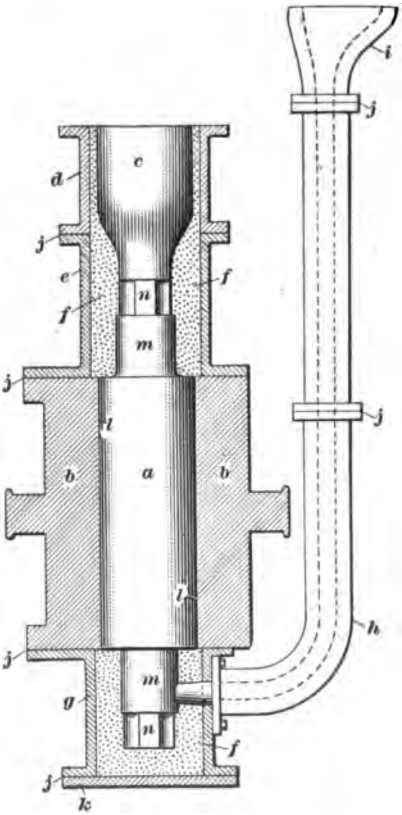


Fig. 1

3. Reading Chill Depth.—When the *chill depth* is spoken of it is understood to mean the depth of clear chill. When reading chill depth, either a clean fracture or a cut taken on the end of the casting at right angles to the chilled surface must be available. The depth of chill can be distinguished readily by the naked eye. In Fig. 2, a section of a casting having a chill depth *a* and a mottled chill *b* is shown.

There are many grades of chilled iron, varying, according to the uses to which they are to be put, from a very mild to a very hard chill. On turning a number of chilled rolls of different grades, it is possible to become familiar with the way they cut; the harder the chill, the more difficult to cut it. When determining the grade of chilled iron in this way, care must be taken to get a good tool, to become familiar with the way it cuts, and to always use tools of the same grade. The degree of hardness of the surface may be readily determined by the scleroscope. The harder and deeper the chill, the more brittle the casting becomes; consequently, to guard against breakage, the chill should never be harder nor deeper than its use requires.

4. **Uses of Chilled Iron.**—Owing to its great resistance to wear, chilled iron is used largely for making chilled rolls.

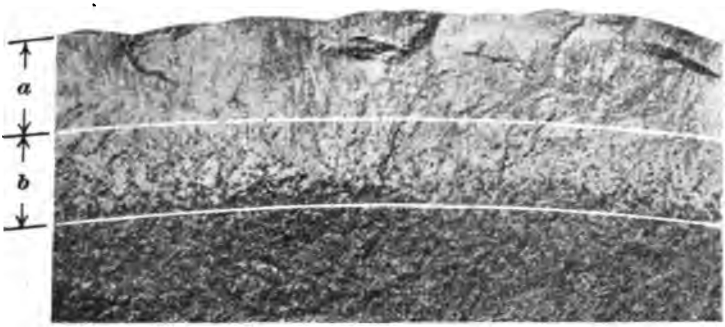


FIG. 2

These rolls are used to roll varied products made from metals, cereals, and other materials. The use of chilled iron is not, however, confined to rolls alone, for the guides for rolling mills, car wheels, rock-crusher plates, dies, anvil blocks, and other articles are made with chilled faces.

MACHINING CHILLED IRON

TURNING AND GRINDING CHILLED ROLLS

5. **Essentials.**—In working chilled iron, good castings are essential. The castings must be free from cracks, blow holes, and dirt, and the chill must be of the right depth. In turning chilled-iron rolls, special lathes must be employed, and a few general rules must be observed to insure successful work. The cutting speed must be so slow that the tool will hold its edge until it has done a reasonable amount of work. The lathe must have a large amount of power, and the tools and the lathe must be of rigid construction. The tool steel employed must be the best, and selected according to the character of work.

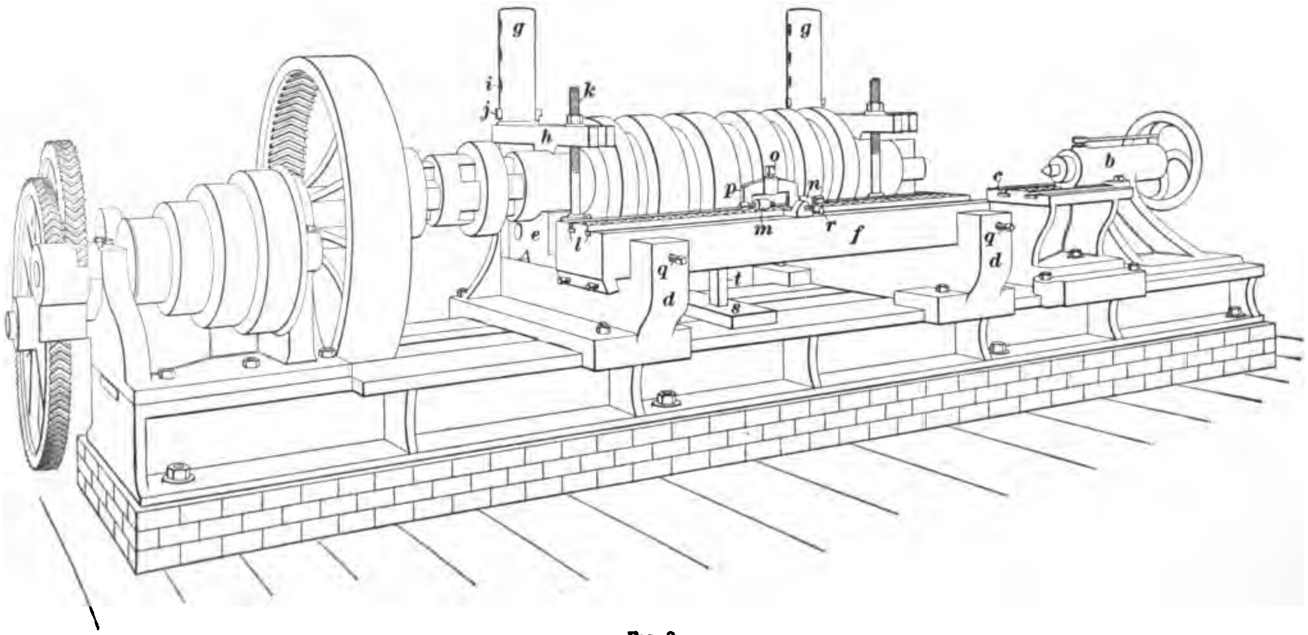


FIG. 3

TURNING SOLID ROLLS

6. Lathes for Turning Chilled Rolls.—A type of lathe for turning rolls cast solid and having journals, or *necks*, as shown at *m*, Fig. 1, and driving ends, or *wabblers*, as shown at *n*, is illustrated in Fig. 3. In common with all lathes used for turning chilled iron, this lathe is powerful and rigid in construction. The bedplate is strongly constructed and is securely bolted to a solid foundation. The headstock is provided with double helical gears, so that the pull may be constant and that the teeth of the gears cannot cause hammering or backlash. Instead of the cone-pulley drive the lathe may have a single pulley with a variable-speed countershaft. This latter practice has the advantage that more speeds are possible. A direct-connected, variable-speed motor may be used to drive the lathe. In Fig. 4 is shown a form of roll lathe in which the machine is driven by a single pulley *a* belt-connected to a variable-speed countershaft.

7. In all cases, chilled rolls are turned by feeding the tool crosswise into the roll, the length of the cutting edge of the tool determining the length of surface turned. Consequently, a chilled-roll lathe is not provided with a feed rod to move the carriage lengthwise. The necks and wabblers being soft, the rolls are frequently centered and necked on an ordinary engine lathe. The operation of turning the necks of rolls is known as **necking.** The riser head may also be cut off in the engine lathe. When the rolls are necked on a roll lathe, the center holes are usually made by hand, using a portable drill to operate the drill and reamer.

The tailstock *b*, Fig. 3, is used when turning rolls between centers, as when necking or cutting off riser heads. On large lathes, the tailstock is provided with rollers which can be raised into position when sliding it along the bedplate. The necking rest *c* is used to support the turning tool when necking. It is moved along the bedplate and bolted in position opposite where it is desired to cut. The roll would then be necked by feeding the tool crosswise.

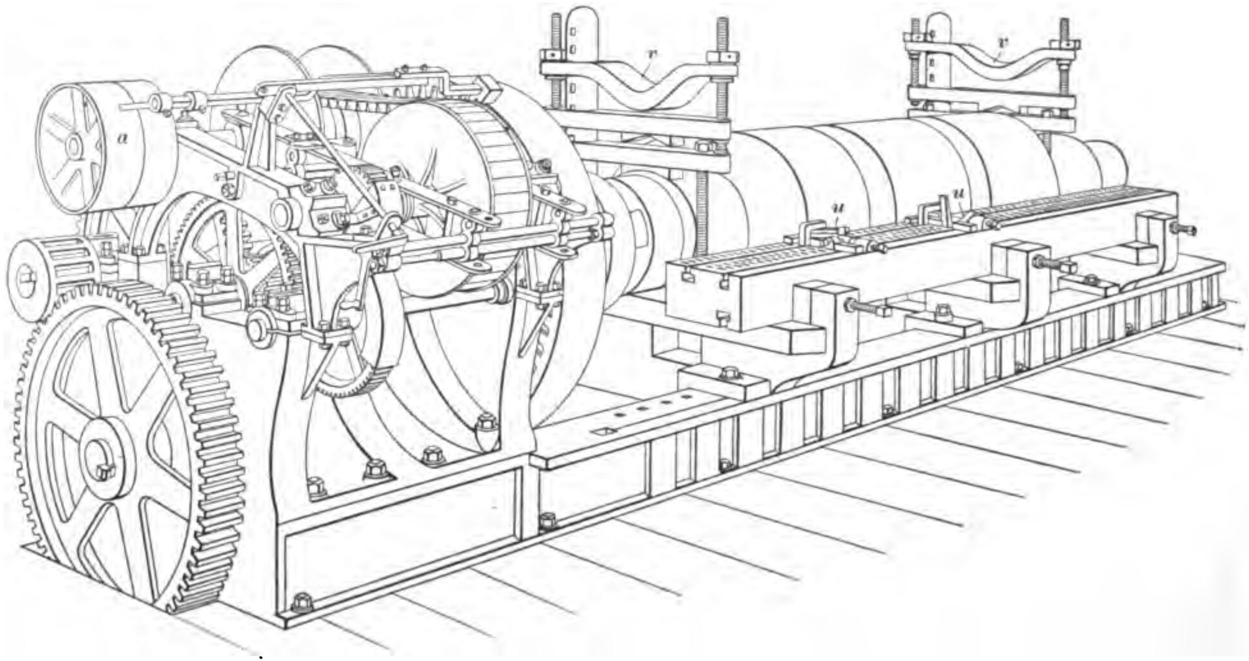


FIG. 4

8. After the rolls have been necked, the tailstock and necking rest are removed and the regular roll-lathe housings *d*, Fig. 3, are placed on and securely bolted to the bedplate. The chucks, or bearing blocks, *e* fit into the housings and form the necessary bearings for the rolls to run in. The tool rest *f*, known as the **piano rest,** is also supported by the housings *d*. The housing posts *g*, which hold the caps *h* in position, and the housings *d* are rigidly connected. The chucks *e* and the caps *h* generally have babbitted faces for the necks to run in. These faces are kept well greased to prevent scoring of the finished necks. In some cases extra bearing blocks are forced between the necks and the housing posts to increase the bearing surface. The caps *h* are made to slip over the housing posts *g* as shown. The housing posts are slotted at intervals as shown at *i* to receive the blocks *j* which prevent the caps from moving upwards. The front end of the caps are held in position by the bolts and nuts *k*. These bolts are keyed to the housings *d*.

9. Material of Tools for Turning Chilled Iron. When working chilled iron, high-speed-steel tools are necessary when heavy and fast cutting is to be done. For this reason, high-speed steel is largely used for roughing tools for chilled iron. As it will not hold a sharp edge, however, it is not adapted to finishing work. High-carbon tool steel hardened in brine does hold a fine accurate cutting edge, and for this reason is chiefly used for finishing tools. It may also be used for roughing work; but this is not advisable if time is an important factor.

10. Solid Turning Tools.—Tools used to work chilled iron are not blocked up from the piano rest, but are made of such depth that, when set up, they will be the desired distance below the center of the work. Clearance on the cutting edge is necessary. A tool set at the center must have a good deal of clearance, making the point weak. A tool set below center can be square, making a stronger cutting edge. Hence, all tools for turning chilled iron, cutting-off tools excepted, are always made and set so that their cutting edges will be below the center of the work. Tools for turning work of large diameter are set farther below center than those used to turn work of small diameter.

11. Different types of tools employed in turning chilled rolls are illustrated in Fig. 5. The **facing tool** used to turn the straight surfaces of chilled rolls is shown in (*a*). It is made from a bar of steel from 1 to 1½ inches square and from 3 to 12 inches long, depending on the work to be done. When making this tool, the stock is first annealed by heating it red hot and cooling it slowly in lime, after which the grooves are formed on a shaper. Each face is now hollow ground, holding the tool parallel with the face of the grinding wheel. The tool is then hardened and touched up slightly on a grindstone, after which the corners are honed to an edge with an oilstone. The **pusher** used to force the tool shown in (*a*) into the roll is shown in (*b*). It may be made of any grade of steel. In use, a copper or brass strip *a* is placed between the facing tool *b* and the pusher *c* to prevent injury to the sharp edges of the tool by the pusher. The pusher must be shaped so that it will bear against the top edge of the tool in order to avoid all tendency to push the bottom part of the tool, to which no resistance is offered, toward the work. If the bottom part of the tool were pushed nearer the work, the clearance angle of the tool would be reduced.

12. One type of **grooving tool** is shown in Fig. 5 (*c*). The exact form of the tool depends on the shape of the groove to be turned in the roll. The tool shown is used to turn flat grooves whose rolling surfaces are parallel and whose sides are perpendicular or nearly so to the length of the roll.

Another type of grooving tool is shown in (*d*). This tool is used to turn diagonal grooves in rolls, as, for example, grooves used to roll squares and diamonds. Both *roughing* and *finishing* tools of this type are used. The roughing tool has a blunt point and is made of high-speed steel. Heavy cutting can be done with this tool. The finishing tool is made of high-carbon tool steel and has a sharp point. To avoid destroying this point, light cuts must, of course, be taken.

13. In Fig. 5 (*e*) and (*f*), forms of roughing tools known as **lip tools** are shown. These tools will remove stock more

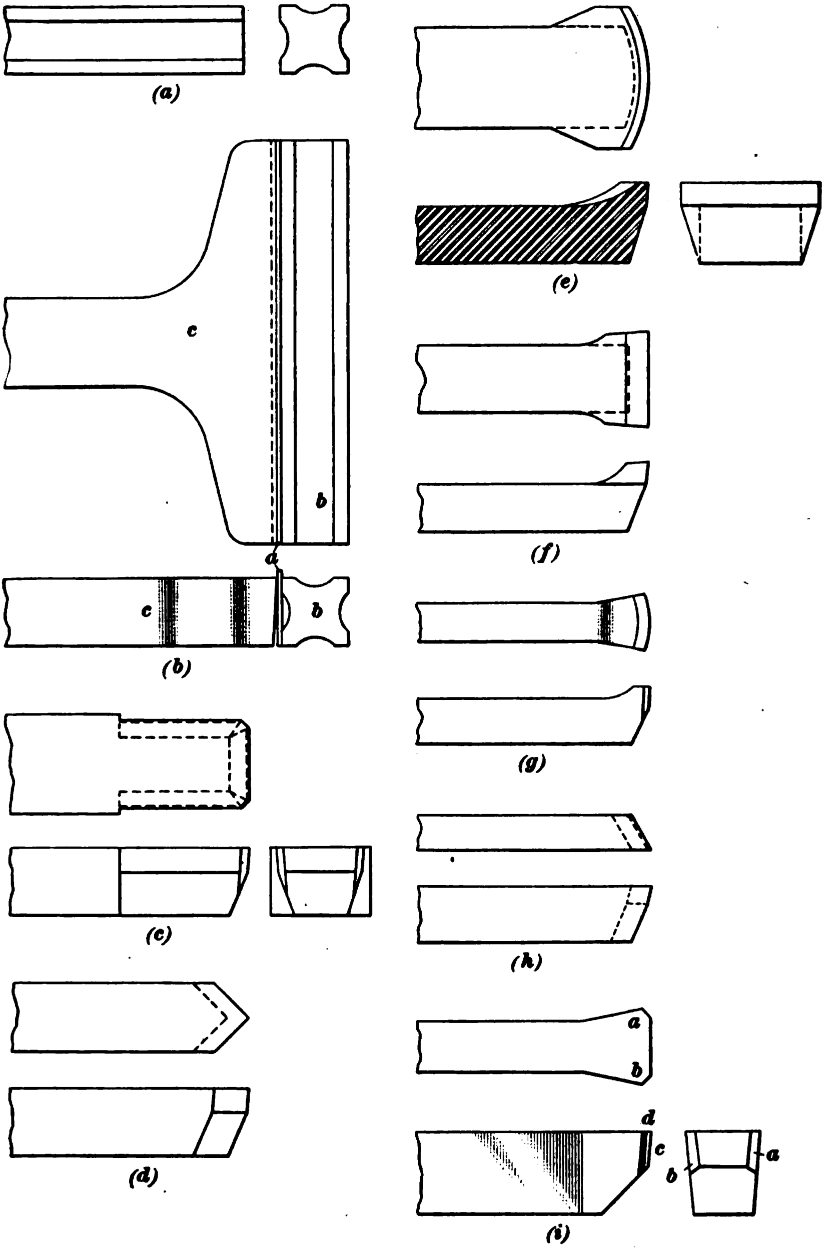


Fig. 5

rapidly than those ground straight on the top. In (*g*) a form of roughing tool similar to that in (*e*), but narrower, is illustrated. It is used to rough out narrow recesses and to cut off riser heads.

In (*h*) the tool for sharpening the corners of the grooves is represented. This tool is employed when cutting off riser heads in the lathe. The tool shown in (*g*) is used first, running the cut down almost to the required depth. Then the tool shown in (*h*) is run in and the corner of the groove next to the roll is sharpened up, so that when the riser head is broken off it will break flush with the end of the roll.

14. One form of **cutting-off tool** is shown in Fig. 5 (*i*). This tool is forged from $\frac{3}{4}$″×1$\frac{1}{4}$″ steel, and is hardened in brine. The edge of the tool is about $\frac{15}{16}$ inch wide and the corners *a* and *b* are cut off at an angle of about 45°. When the corners are ground to this angle, they are not so easily broken when used as would be the case if left square. The front face of the tool is given a little clearance as shown at *c*. This clearance is seldom more than 5°. This cutting-off tool is used to cut through the chilled iron, an ordinary cutting-off tool being employed to cut through the softer iron at the center of the roll.

15. Cutting-off tools must overhang the front edge of the tool rest to a greater extent than the turning tools. They are therefore made deeper from the top to the bottom, and consequently stronger. In use, the top face *d* of the tool shown in Fig. 5 (*i*) is set above the center of the roll, and clearance must be allowed on the face *c* as shown. When it is necessary to have a tool overhanging the front edge of the tool rest, the tool prop *t*, Fig. 3, and the bar *s* that support it are used. The tool prop is made just the right length and is placed under the front edge of the tool. This relieves the stress on the tool, making it possible to use lighter tools.

16. It was formerly considered good practice and economy when making wide tools to use tool steel for the cutting edge only and weld the tool steel to a shank made of machinery steel. However, it takes time to make the weld and the tools are often lost by cracking in tempering. Tools made of solid tool steel can always be used or changed to other shapes, where the welded tool would have to be scrapped. For these reasons, modern practice favors the use of solid rather than welded tools.

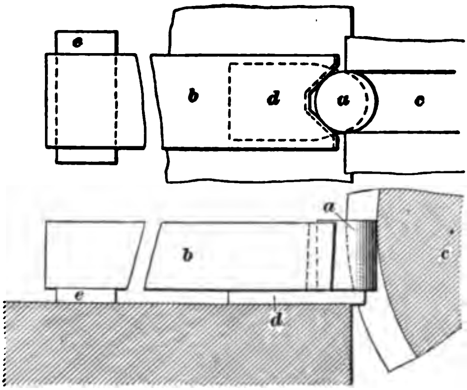


Fig. 6

17. A tool for turning small round and oval grooves is shown in Fig. 6. The tool *a*, called a **plug,** is a cylindrical piece of tool steel with both ends squared and ground. The **push-up** *b* is used to force the cutting edge into the roll *c*. The tool is supported on the blocks *d* and *e*, which are of such thickness that the cutting edge of the tool will come about $\frac{1}{8}$ inch below the center of the roll. Any portion of either the top or bottom end of the plug may be used to cut the groove. In case both ends are dull, the plug may be resharpened by grinding its ends. The block *d* forms a rest for the plug; prevents the tool from digging in, thus marking the main rest; and also prevents the tool from tipping over when the grooves are turned deep. The push-up is made with clearance so that it will bear against the top of the plug as in the case of the facing tool.

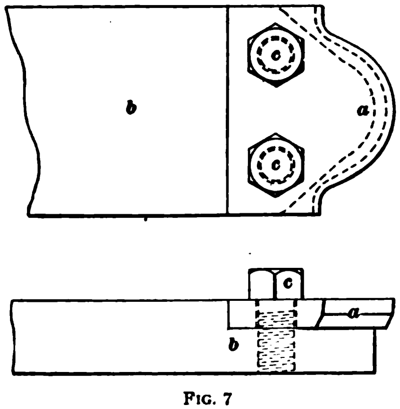


Fig. 7

18. Built-Up Turning Tools.—In Fig. 7 a built-up tool for turning large grooves is shown. The tool is used chiefly to turn circular grooves; but tools are also made to turn irregularly shaped grooves. The cutting portion *a* of the tool is made of high-speed tool steel for the roughing, and high-carbon tool steel for the finishing operations; the tool block *b* is made from machinery or any other kind of steel available. The tool is fastened to the block by the bolts *c*. This form makes a good substantial tool. The tool block may be used to hold different cutters.

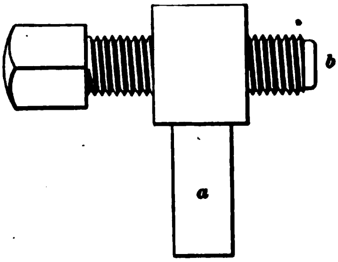


FIG. 8

19. Holding Tools. Owing to the severe stresses to which tools for working chilled iron are subjected, they are not held in an ordinary tool post, but are clamped very rigidly to the tool rest *f*, Fig. 3. This rest is provided with two **T** slots *l* and with rectangular holes in its upper surface, as shown. These rectangular holes are fitted with dogs *m* and *n*. The dog *m*, a larger view of which is shown in Fig. 8, is similar to the ordinary planer plug, and the shank *a* is square or rectangular, depending on the form of the holes in the rest. The end *b* of the setscrew is brought in contact with the tool or the blocking. The dog *n*, Fig. 3, is of the general form shown in Fig. 9, and is arranged to fit into a **T** slot, indicated by the dotted lines. The lug *a* is so formed that the dog can be easily removed from the **T** slot by simply lifting up on the head of the setscrew *b*, and when the end *c* of the setscrew is brought against the work, the lug *a* will take hold of the **T** slot and hold the work firmly in place. The tools are held from behind and at the sides by means of the dogs just described, and are held down by means of the setscrew *o* in the clamp *p* shown in Fig. 3. The tool and rest are advanced toward the roll by turning the screws *q*, and the tool only by turning the screw *r*. The tool is forced into the roll

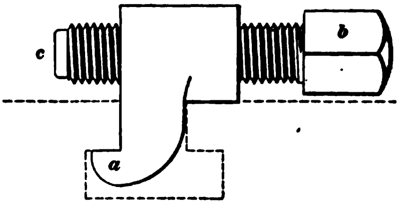


FIG. 9

by turning the screw *r*. The screws *q* are used merely to back up the rest, so that when the tool is cutting it will not force the rest back from the face of the roll. It is not necessary to have the rest parallel to the axis of the roll. When cutting deep grooves the tool extends rather far out in front of the tool rest and must be supported. This may be done by the use of a prop bar *s*, and the prop *t*, on which the front edge of the tool rests.

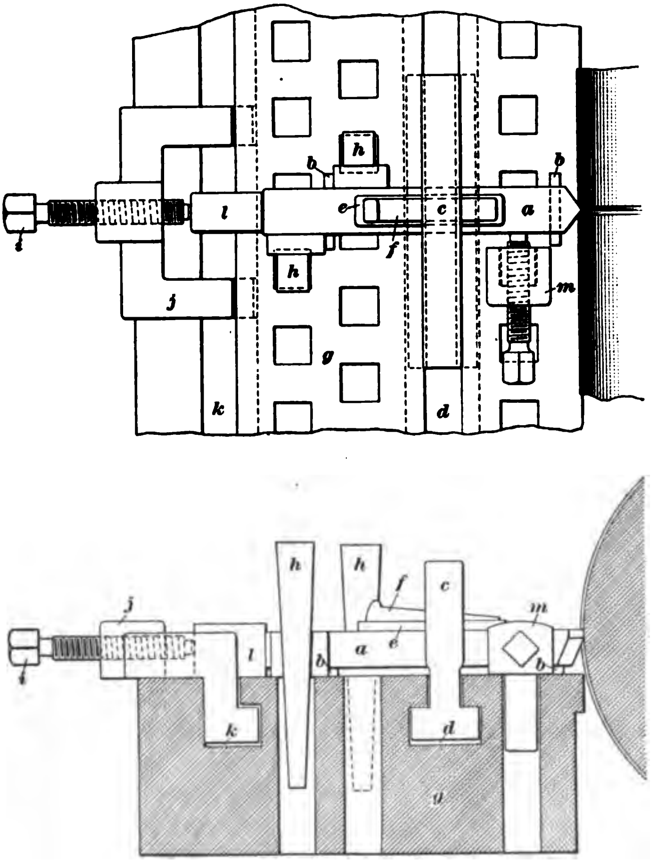


FIG. 10

20. The device *u*, Fig. 4, for holding the tool is shown in detail in Fig. 10. The tool *a* is set on two pieces of packing *b* to bring it up to the correct cutting height. The saddle *c*, which works in the **T** slot *d*, together with the block *e* and wedge *f*, keeps the tool forced against the tool rest *g*. The wedges *h* hold the tool at right angles to the work as it is advanced into the roll by the screw *i*, which works in the pusher *j*. This pusher is held in the **L** slot *k* of the rest. The block *l* is placed between the tool and the screw, in case the tool is not long enough to reach to the screw. Screw blocks, as shown at *m*, are sometimes used in place of the wedges *h*.

21. **Grinding Turning Tools.**—To secure a straight edge on the tool, it is ground on a grinding machine provided with a carriage or special tool holder. The sides of facing tools are ground concave, or hollow, as shown in Fig. 11. In this way two sharp edges *a a* and *b b* are produced. The marks left by the grinding wheel are removed by rubbing an oilstone over the face of the tool. The tool is first set to use one edge as *a a* and when dull, the tool is turned over and the other edge *b b* is used.

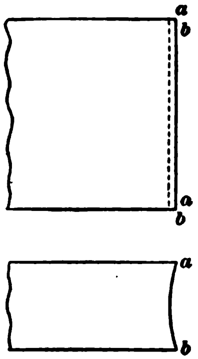


FIG. 11

22. A type of wet grinding machine provided with a carriage and used to sharpen tools for cutting chilled iron is shown in Fig. 12. The machine is fitted with a slide *a* to which the tool is clamped at *b*. The depth of the cut is regulated by the screw *c* and the clearance angle by the screw *d*. The tool is fed back and forth across the face of the grinding wheel by means of the hand wheel *e*, a pinion engaging with the rack *f*, which is secured to the bottom of the slide *a*. With this device, tools may be ground accurately and quickly.

23. **Cutting Speeds.**—To a great extent the cutting speed depends on the character of the chilled iron being turned and the diameter of the roll. On small rolls a surface speed of from 34 to 36 inches per minute is good practice, while for large rolls a surface speed of from 28 to 30 inches is used. A surface speed of 40 inches per minute is probably as high a

speed as could be employed with good result, although a speed of 11 feet per minute has been obtained on very mild chilled iron. In this case the tool steel used was exceptionally good.

24. Cutting Feeds.—In turning chilled iron, the tool is never fed along the work lengthwise, but at right angles to the face being turned. This feeding is done by hand through the use of a wrench and screws. The amount of feed depends on the hardness of chill being turned, the size of the roll, and the strength of the lathe and its attachments. On a roll of mild chill and large diameter using a high-speed-steel tool of the form shown in Fig. 5 (*f*) on a very rigid lathe, a cut $\frac{3}{64}$ inch deep may be taken. This is the deepest feed that may be used on chilled iron, and it is not practicable to employ it, as the tools will stand up for a short time only and the wear on the lathe is excessive. Ordinarily a cut of about $\frac{1}{64}$ inch deep is considered a good average cut. In turning a plain chilled roll a tool of the form shown in Fig. 5 (*a*) is used. Cuts .01 inch deep may

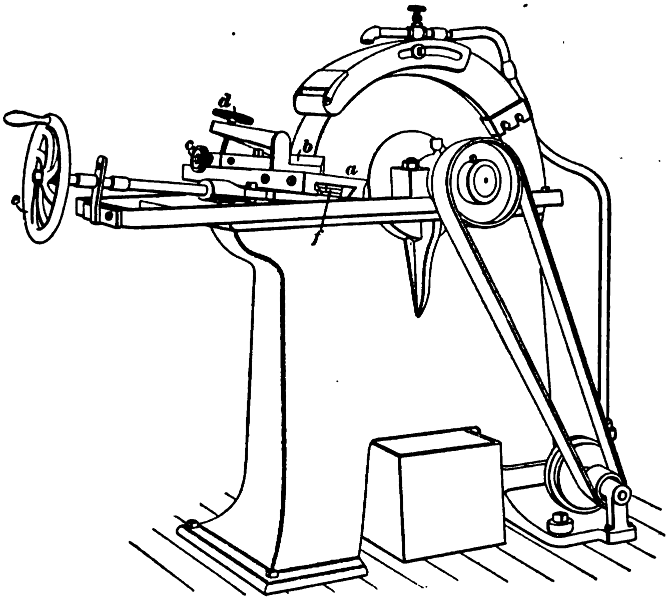


FIG. 12

be made with this tool. This depth of cut is, however, rather excessive, the normal depth being about .003 or .004 inch.

25. Setting Up Roll in Lathe.—The center holes of chilled rolls include an angle of 60°, and their width across the mouth varies from ½ to 3 inches. For a 500-pound roll, a width of mouth of 1 inch, and for a 2,000-pound roll, a width of mouth of 2 inches, is good practice. As all rolls are cast on end, the bottom, or drag, end is necessarily more solid and true than the top, or cope, end, sometimes called the riser, or head, end. The top face of the riser head is piped considerably and is very rough and irregular, owing to shrinkage, feeding, and dirt. For these reasons, the cope end is not centered, a *false center*, Fig. 13, being attached to it by means of the setscrews *a*. This false center contains a center hole *b* which receives one of the lathe centers. The drag end of the roll is centered as usual, and the roll is put on the lathe centers with the false center on the tailstock end. By adjusting the screws *a*, the work may be adjusted until either the wabblers or the body runs true. The usual practice is to set the large rolls so that the bodies run true, and the small rolls that are to run at a high speed in the mills, so that the wabblers run true. If these fast-running, small rolls were not turned true to the wabblers, the wabblers would probably break off in service.

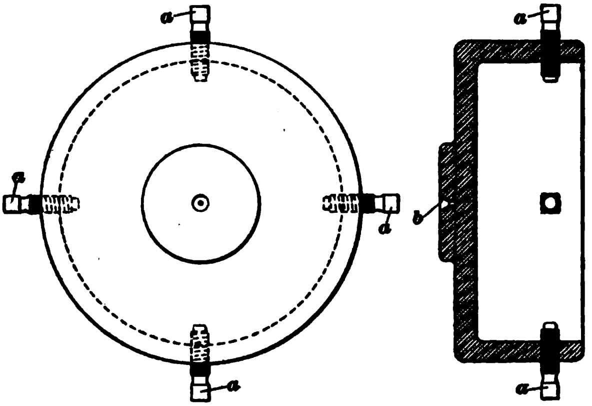


FIG. 13

26. Testing Casting.—Before finishing the roll, it is tested for chill depth, evenness of chill, and flaws. To test for chill depth, take a cut over each end of the roll, using a tool of the form shown in Fig. 5 (*f*), and observe the depth of chill as explained in Art. 3. The drag end usually has a deeper chill than the cope end. The evenness of chill may then be discerned by following the line of clear chill around the body. When in cooling and shrinking the roll leans to one side of the chill, the depth of chill on that side will be the greater, the opposite side having a shallow chill depth. If this condition is very marked, the roll is made unfit for use. A few cuts are taken on the surface of the body of the roll, using a tool of the form shown in Fig. 5 (*f*), to determine whether it will true up without flaws.

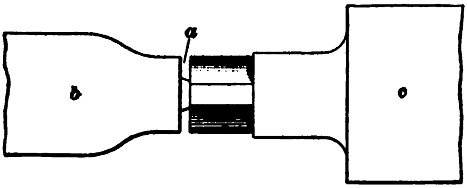


FIG. 14

27. Cutting Off Riser Head and Necking.—If, by testing, the roll has been found to be satisfactory in all respects, the riser head is cut off. This may be done by using a round-nosed lip tool like that illustrated in Fig. 5 (*g*), cutting into the roll as shown at *a*, Fig. 14, the tool being secured to the necking rest *c*, Fig. 3. A deep groove is made, the corner being sharpened with a tool of the type shown in Fig. 5 (*h*). The roll is then removed from the lathe and the riser head *b*, Fig. 14, is separated from the body *c* by means of wedges and a few blows with a sledge. The cope end of the roll is now centered, and the roll is put on the lathe centers and necked—that is, the journals are trued up. The necks are now turned to size unless they are to be ground and polished. In this case a little stock is left. As this part of the roll is not chilled, the lathe is run at the regular gray-iron speed except when cutting near the body where chill will be found.

28. Turning Body of Plain Roll.—After necking, the roll is removed from the centers, the tailstock and necking rest are taken from the lathe, and the housings *d*, Fig. 3, are set up in place. The roll is caused to turn in the bearings *e* by the driver *a*, Fig. 15 (*a*) An end view of the driver is shown in Fig. 15 (*b*). The driver fits over the spindle *b*. This spindle is shaped like the wabbler *c* and is connected to it by the box *d*. The lathe face plate *e* carries the lugs *f*, and as the face plate revolves these lugs come against the lugs *g* of the driver, causing rotation. In the figure, *h* is the neck and *i* the body of the roll. The rolls are run in bearings rather than on the centers when turning the body, because the centers do not always wear uniformly during the turning process, and consequently the part of the roll turned last would not be concentric with that turned first.

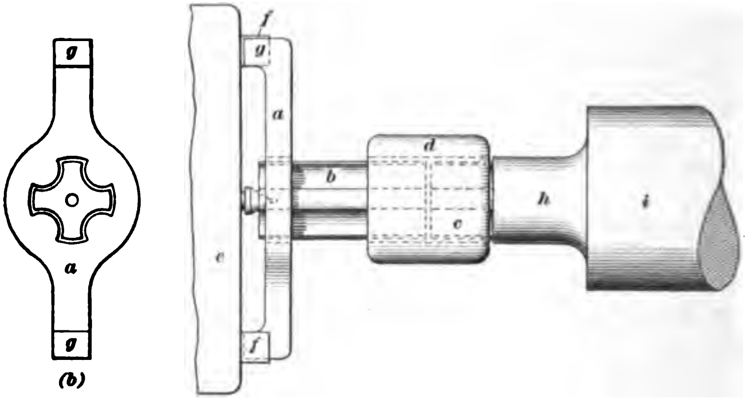


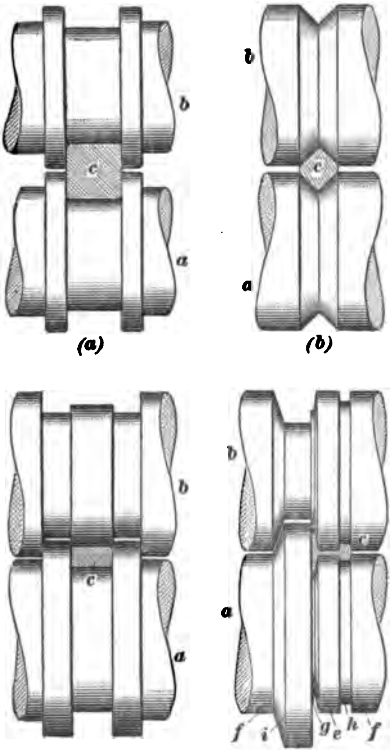
FIG. 15

A facing tool, Fig. 5 (*a*), made of high-speed steel is set up against the surface to be turned, the pusher, Fig. 5 (*b*), is placed against the facing tool, and the pusher is held as shown in Fig. 10. By turning the screw *i*, Fig. 10, the tool working against the pusher is forced into the roll and is adjusted until both ends of the portion of the roll turned measure the same. The part of the roll corresponding to the length of the cutting edge of the tool is now turned to the required diameter. All measurements are made with plain calipers.

The tool and pusher are now taken out and reset further along the roll where the tool is forced in as before until this part of the roll is the same diameter as that previously turned. This process is continued until all parts of the body are turned to the same diameter.

29. The finishing tool, made of high-carbon steel, is next set up in the same manner, and very light cuts are taken until the entire length of the roll body is the same diameter. In case the roll is to be ground and polished, it is not finished quite as carefully in the lathe as would otherwise be done, as it will be trued up accurately on the grinding machine. A little stock, about $\frac{1}{64}$ inch, must be left on rolls to be ground.

30. Testing for Straightness of Surface. The surface of the roll is tested for straightness before removing the roll from the lathe. A straightedge, which has been chalked on its edge with soapstone or hard chalk, is placed lightly on the finished surface and parallel to the axis of the roll. The straightedge is now moved lengthwise about $\frac{1}{16}$ inch, back and forth to produce a rubbing action on the roll. The chalk is thus transferred to the roll at every point of contact. If the roll is finished straight, a line will be transferred on the roll; if the roll is not straight, marks will be found on the high spots only. This test is accurate and reliable, can be easily and quickly made, and is the one commonly used.



(a) (b) (c) FIG. 16 (d)

31. Kinds of Grooved Rolls.—The surfaces of grooved rolls which work together are called **passes.** When the collars, or projecting rings, of one or more grooves fit into corresponding recesses in the other roll, the roll is said to have **closed passes**; if the collars do not fit into corresponding recesses, the roll has **open passes.** In Fig. 16 (*a*) and (*b*) are shown examples of grooved rolls with open passes, and in (*c*) and (*d*) grooved rolls with closed passes are illustrated. In the illustrations, *a* and *b* are the rolls and *c* the work being rolled.

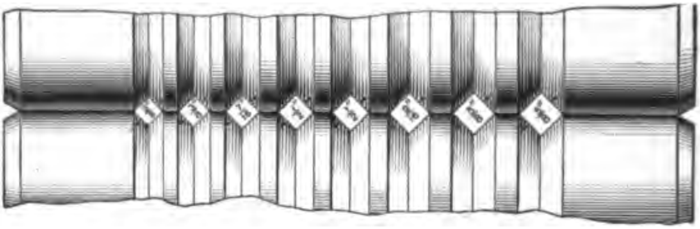


FIG. 17

32. Templets for Open Passes.—The passes in grooved rolls are turned to fit templets that are generally made of sheet steel or zinc about $\frac{1}{16}$ inch thick. In making templets for open passes either the individual or group method may be followed. Let it be required to make templets for the passes of the rolls shown in Fig. 17. If the individual method is used, a series of templets as shown in Fig. 18 (*a*) are made, and if the group method is followed, the templets are all formed in a single tool as shown in Fig. 18 (*b*). The group method has an advantage in that all the templets for a certain set of grooves are arranged together; but it can only be used for small grooves, for if made for large grooves it would be too clumsy to handle. If no measurement of the templet is over 3 inches, its size is not objectionable. The templets are made so that the wings *a*, Fig. 18 (*a*), on either side of the part *b*

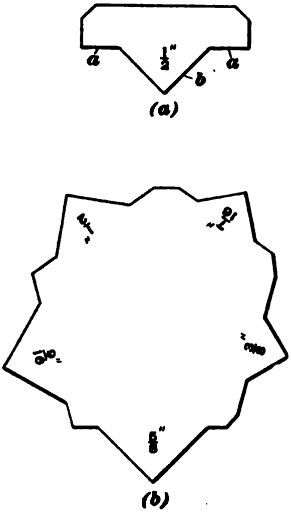


FIG. 18

corresponding to the groove will rest upon the collar of the roll, forming an exact gauge for the depth of the groove.

33. Turning Grooved Rolls With Open Passes.—The shapes of the grooves and their positions in the rolls are determined from the drawing, when turning grooved rolls with open passes. Suppose the drawing, Fig. 17, calls for rolls to roll square bars on the diagonal. As the grooves are, in this case, identical in both rolls, the same tools and templets may be used for both. A roughing tool of high-speed steel and a finishing tool of high-carbon steel of the form shown in Fig. 5 (*d*) are made, the point of the roughing tool being ground off and that of the finishing tool being left sharp. Templets are made to the dimensions of the drawing, those made of steel being preferable to those made of zinc, as they are less easily distorted or damaged.

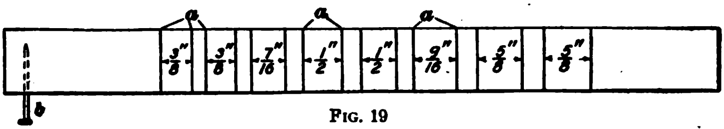


FIG. 19

34. That the grooves in one roll may coincide and be directly over those in the other roll, a **strip,** Fig. 19, is made. This strip is a piece of wood from 2 to 4 inches wide, ½ to 1 inch thick, and a little longer than the roll body. Lines *a* corresponding to the edges of the grooves are marked on the edge of the strip, and a nail *b* is driven in the end at a distance from the last line marked on the edge equal to the distance shown by the drawing, from the end of the body to the edge of the groove. In use, the strip is held on the body of the roll with the nail against the end of the roll, thus being always held in the same relative position with the roll. By using a strip to locate the positions of the grooves in the rolls, and templets for the size and shape of the grooves, any number of rolls may be turned alike.

To test the fit between the grooves and templets, a piece of white paper is held behind the roll, or rolls, so that a light from some source will shine directly on it. The templet is then held in the pass and if it fits perfectly no light can be seen between it and the roll. If the groove is not correctly shaped, light will be seen between the templet and the roll.

35. Templets for Closed Passes.—The outline of templets for closed passes is made to correspond to the complete outline of the work to be rolled instead of one-half of this contour, as in the case of templets for open passes. This is necessary as, when fitting the templet to the rolls, they must be together, and consequently a templet of the form described for open passes could not be used. A convenient method of holding closed-pass templets is shown in Fig. 20. The templet *a* is held on the rod *b*, which is about $\frac{1}{8}$ inch in diameter. The end *c* of this rod is threaded to receive a nut *d*, and has a shoulder *e* against which the templet rests. A hole whose diameter is about $\frac{1}{32}$ inch larger than that of the threaded end is drilled in the templet, and the templet is secured to the rod. In use, the tool is held by the handle *f*.

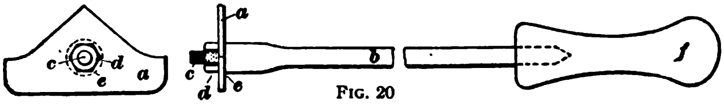


FIG. 20

36. Turning Grooved Rolls With Closed Passes. Grooved rolls with closed passes are sometimes called *collar-and-groove rolls.* They must necessarily be fitted together when turning. This is done by finishing one roll, generally the collar roll, which is the roll carrying the extending part, and then turning its mate, the groove roll, which is the roll recessed to receive the collars, while the finished roll is carried above it on straps shown at *v*, Fig. 4.

37. Suppose the rolls shown in Fig. 16 (*d*) are to be grooved, their bodies having been otherwise turned. As was done when grooving rolls with open passes, a strip, Fig. 19, is made, the division marks being laid off on it in accordance with the drawing. This strip serves as a gauge when spacing the grooves and collars. The collar roll *a*, Fig. 16 (*d*), is finished first. To lay off the grooves, a chalk mark is drawn along the body of the roll parallel with the axis, the strip is placed upon this chalk mark, a pencil line is drawn the length of the roll, lines are then also drawn on the roll corresponding to the divisions on the strip, and prick punch marks are made at the intersections of these lines.

38. After laying out the location of the grooves and collars, the body of the roll is rough grooved nearly to size. The parts *d*, *e*, and *f*, Fig. 16 (*d*), are now turned to size, and the groove *g* is finished, using a tool of a shape corresponding to that of the groove and the strip and templet as gauges. The tool is fed in until the groove is of the correct shape as shown by the templet. The templet employed in this case is made especially for the groove that forms the flange of the work. The groove *h* is next turned to size, using a tool of the shape of the groove, which is finished to the strip and the complete templet. The part *i* is now turned, using the strip as a gauge, and the roll is removed from the lathe and placed on the straps *v*, Fig. 4, after the groove roll *b* has been set in the housings.

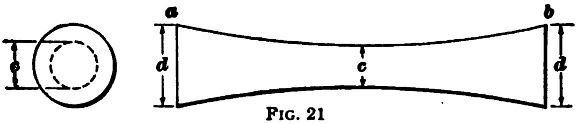


FIG. 21

The groove roll is now laid off and grooved as was done in the case of the collar roll, except that the straps carrying the collar roll are let down gradually as the groove roll is being finished until the rolls are the same distance apart that they are to be run in the mill. The groove is then finished to fit perfectly the templet, which is held on a rod.

39. Turning Concave Rolls.—Rolls used to roll sheet metals may be of either the hot or cold type and are not grooved. *Hot rolls* are those used to roll hot sheets, and *cold rolls* are employed to roll cold sheets. Owing to the greater expansion in the center part of the rolls when hot, hot rolls are usually made concave, as shown exaggerated in Fig. 21. The shape of the roll is that of a regular curve *a b*. The smallest diameter *c* of the roll is at the center and the largest diameters *d* are at the ends. The rolls are made of such form that when they are brought together with their axes crossed a certain amount, the contact between the rolls will be a straight line. In operation, the rolls are not crossed. The cross of the rolls is measured by placing a straightedge on the roll at such an angle that no light can be seen between it and the roll, drawing one line along the straight-edge, and another line touching the first line at one end of the roll body and parallel to the roll axis, and measuring the distance between these lines at the other end of the roll body. This distance is known as the *cross of the roll*. The cross of the rolls usually varies from 2 to $3\frac{1}{2}$ inches.

Concave rolls are turned so that when a straightedge is placed on them at the proper angle, no light can be seen between it and the rolls. The cutting edge of the tool used for turning the rolls is slightly rounded. Both ends of the rolls are turned to the same diameter, and the center is turned the required amount smaller. Cuts are then taken on the body of the roll until the desired shape and finish are obtained.

40. Size of Rolls for Working Hot Iron.—In turning grooves for rolling-mill work, the grooves must be made somewhat larger than the standard bars they are intended to roll. To meet these requirements, an allowance of $\frac{1}{64}$ inch per inch of diameter is usually considered sufficient. For instance, a tool to cut a groove for rolling a 1-inch round bar would have to be $1\frac{1}{64}$ inches in diameter, and a groove for rolling a $3'' \times \frac{1}{2}''$ flat bar would have to be $3\frac{3}{64}$ inches wide, similar allowances being required for all shapes.

41. Returning Worn Rolls.—Rolls that have been worn from use are usually returned. It will be found that a very hard skin, almost impossible to cut, has been formed on the surface. This skin is very thin and is removed by taking a heavy cut, getting under the skin, before truing up the surface accurately with light finishing cuts. If light cuts are attempted before removing this skin, the tool will be dulled. High-carbon steel is used for both the roughing and finishing tools, as high-speed steel will not retain a good cutting edge.

TURNING HOLLOW ROLLS

42. Lathe for Turning.—Rolls for flouring mills, calendering rolls for paper mills, and rolls for other similar purposes are generally cast hollow and chilled on the outside. These rolls are usually turned on a special type of lathe, Fig. 22, and, in the case of flouring-mill and calender rolls, are ground to a perfect finish while running on their own bearings.

Both spindles of the lathe are made hollow and the roll is introduced through them and the collars *a*, Fig. 22, and is held in position by the setscrews *b*. In the lathe shown, both spindles are fitted with gears, the roll being driven from both ends, thus increasing the rigidity of the lathe. The shaft *j* is driven by any convenient means. The pinion is keyed to this shaft and drives the gear which is keyed, together with the pinions which drive the spindle gears, to its shaft. This style of lathe is not provided with a carriage having a feed parallel to the length of the lathe, but simply with a broad tool post *d* fitted upon a cross-slide *c* that can be fed along the ways *e* by means of the feed-screw *f*.

Lathes driven from one end only are also used for turning hollow rolls. In this case, the tailstock end of the lathe is made with a hollow spindle through which the roll can be introduced.

43. Holding and Driving Work.—Hollow rolls are first set up in the lathe; the chilled surface is then turned, and the ends are cut off, after which the rolls are bored and fitted to a center piece which forms the shaft and journals. Ordinarily, in turning 10- or 12-inch rolls that are to be bored and mounted subsequently, the roll is held by means of eight setscrews at each end, these setscrews also acting as drivers. Fig. 23 illustrates the general method of driving. In Fig. 22 can be seen the collar *a* through which the setscrews *b* are passed to hold the work. The same letters have been used for referring to these parts in Fig. 23. The roll *r* is centered and held by means of the setscrews *b*. This method of adjusting and driving the roll enables the workman to center the chilled part very carefully, so that

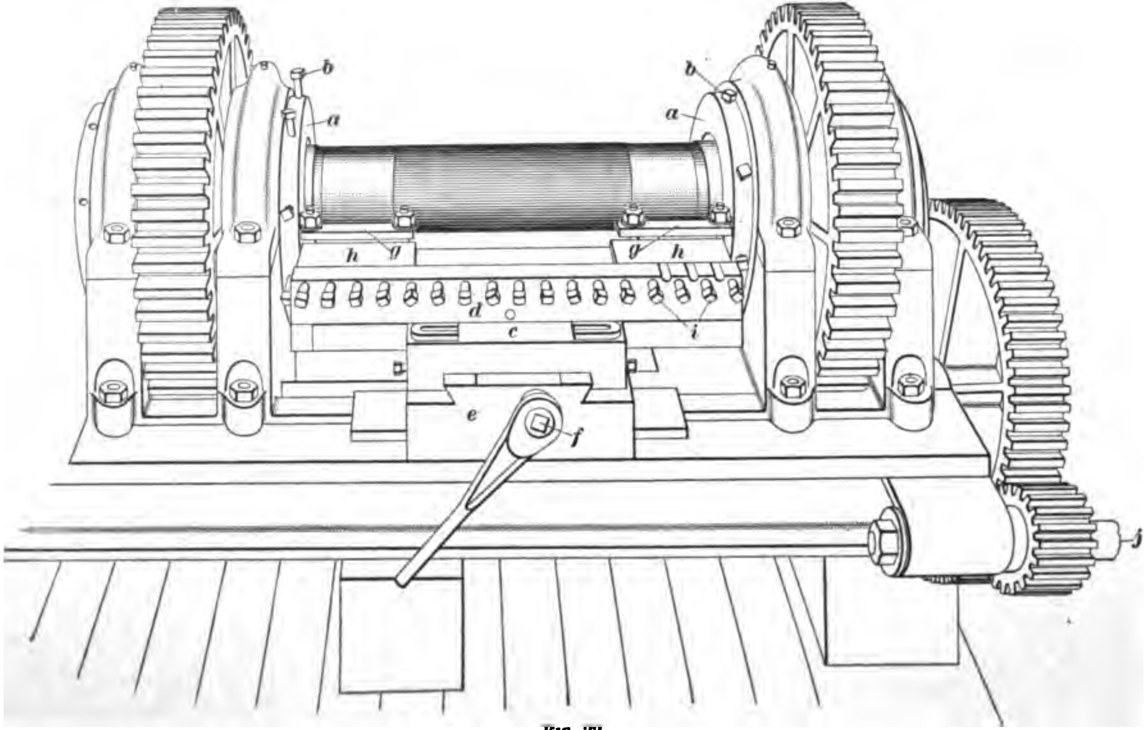


FIG. 22

the amount of turning required will be as small as possible. There is generally about $\frac{1}{8}$ to $\frac{3}{16}$ inch of stock to be turned from chilled rolls, and as the turning process is very slow it is important that the centering be done accurately and carefully.

44. **Holding Lathe Tools.**—Tools for turning hollow chilled rolls must be clamped to the lathe tool rest very rigidly. The method of holding the tools is illustrated in Figs. 22 and 23. In Fig. 23 the tool *c* is set on the carriage *h* and clamped down by means of the strap *e*, which is held in position by two bolts *f*. The tool is forced against the rolls by means of a series of setscrews *g*. Care must be taken that the front face of the rest is close to the roll, as shown at *i*. The closer this rest is to the roll, the less danger there will be of breaking the front face of the tool. The flat tools employed for this work may be originally $\frac{1}{2}$ in. × 5 in. × 5 in. If the tool is ground on one face only, but two cutting edges can be obtained from one grinding. If the tool is ground on both faces, as *j* and *k*, four cutting edges will be obtained. When these have been dulled,

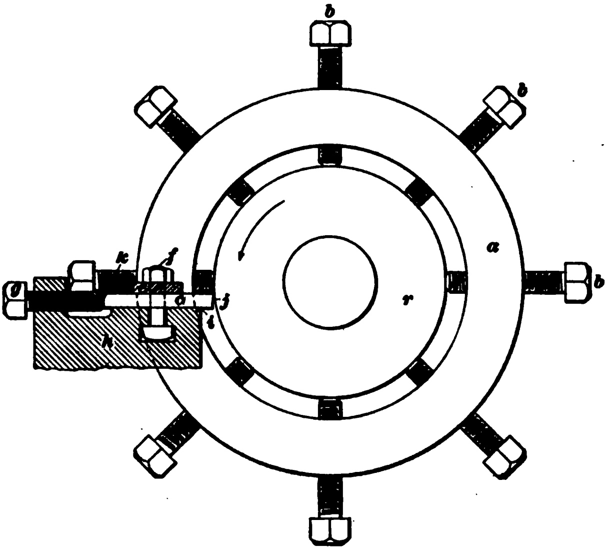


FIG. 23

the tool is ground again, and each succeeding grinding makes it narrower. Tools can be used until they become so narrow that they can no longer be held by the clamps *e*. In Fig. 22, the clamps can be seen at *g*; in this case very narrow tools are being employed and packing pieces *h* are placed behind them for the setscrews *i* to bear against.

45. The upper edge of the tool *c*, Fig. 23, is set ½ inch below the center of the 10-inch roll. This, together with the concave form of the face, will give the proper amount of clearance. In setting cutting-off tools, they are clamped by means of one or more clamps similar to *e*, Fig. 23, and the back end of the tool is set against a setscrew or a packing piece held by two or more setscrews. Cutting-off tools must overhang the front edge of the rest *i*, Fig. 23, to a greater extent than turning tools, and consequently it is necessary to have the tool deeper from the top to the bottom, so that it may be stronger.

After the tools have been clamped in place they are fed to the work by means of the feed-screw *f*, Fig. 22, and are kept parallel with the face of the work by adjusting the setscrews *i*. The shavings cut from the roll resemble very fine needles or gray hair.

46. Turning Hollow Rolls.—The tools commonly employed for turning hollow rolls are flat broad-nosed or wide-faced tools. It is probable that ½ in. × 5 in. × 5 in. is about an average size for straight work. In turning cylindrical rolls two tools are commonly operated at a time, thus turning 10 inches of the face of the roll. At first thought it might seem best to use one tool 10 inches wide; but it is difficult to harden so wide a tool without cracking it; narrow tools are far less likely to break, and on the whole there is greater economy of steel and less difficulty experienced in adjusting tools when the two 5-inch tools are employed in place of one 10 inch. All tools for turning chilled iron differ radically from those employed on softer metals, and all the turning is of the nature of scraping, the tools being given but little, if any, clearance.

47. When cutting off the ends, the roll is never entirely cut off on the lathe, but is cut down until it has a shell about

¼ inch thick about the core. It is then removed from the lathe and iron wedges are driven into the cut made by the cutting-off tool to force the end off. The roll is bored with ordinary tools in another machine, the central portion of the roll being soft.

GRINDING CHILLED ROLLS

48. **Roll-Grinding Practice.**—Chilled rolls intended for use in flouring mills, calender rolls for paper-making machinery, and others requiring a smooth, cylindrical surface are finished by grinding. The necks as well as the bodies of the rolls may be ground. In some cases the necks are left as they come from the lathe and in others they are ground previously to grinding the bodies. If the necks are not cylindrical and the rolls are ground while they are running in bearings, the body of the roll will not be ground cylindrically. For this reason, where accuracy is required, the necks are generally ground.

49. **Poole Grinding Machine.**—The J. Morton Poole grinding machine is much used to grind large rolls. It is arranged with the grinding wheels in swinging frames to grind the roll cylindrically, regardless of slight inaccuracies of the ways. To secure the best results in grinding a roll on this machine, the necks must have been previously ground true, by grinding on dead centers in the usual way on a cylindrical grinding machine of the ordinary type.

50. **Cylindrical Grinding Machine.**—A cylindrical grinding machine adapted to roll grinding is shown in Fig. 24. It can be used to grind both the necks and bodies of the rolls, the necks being ground on dead centers, and the bodies while the necks are running in bearings. This machine is similar to the cylindrical grinding machines in ordinary use, being of the type in which the table *a* is stationary while the grinding wheel *b* and the carriage *c* which contains it, traverse past the work *d*. This type of machine is especially adapted to the grinding of long heavy rolls, as the roll does not traverse back and forth when grinding. The table of such a machine is more rigid and less floor space is needed.

51. The grinding wheel is driven by a belt *e*, Fig. 24, operating from the main drive shaft *f*. This shaft extends the entire length of the machine, and from it the different mechanisms are driven independently through belts. It is protected by a sheet-metal guard *g*. The grinding-wheel belt *e* passes over idlers *h* that are arranged so that the belt is maintained taut on the pulleys as the wheel head is moved on the cross-slide. The carriage *c* travels lengthwise on the **V** *i* and the flat *j*. These ways are protected from grinding dust and dirt by the guards *k*. When grinding the necks of the roll, the roll is supported on dead centers in the usual way. When grinding the body of the roll, the necks rest in the bearings *l*, the roll being connected to the headstock, not shown, in any convenient way to cause rotation. The headstock spindle and the main shaft *f* are driven by a motor located at the end of the machine, not shown. They may be driven, if desired, by belting connected to an overhead countershaft. A liberal supply of soda water is furnished to the wheel when grinding by the pump *m* through the hose *n*. The speeds and feeds of the machine are controlled by hand wheels and levers.

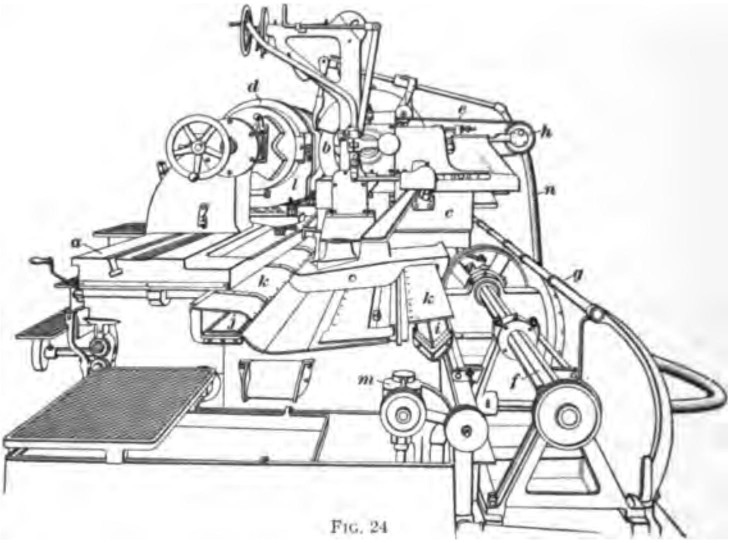


FIG. 24

52. Selection of Grinding Wheel.—In grinding chilled-iron rolls, as in turning them, the degree of hardness of the metal will, to a great extent, govern the working of it, the softer roll being ground much more rapidly than the harder. The selection of the grinding wheel must be made with the aim in view of producing a highly polished surface and a rapid removal of stock. The harder the iron, the softer in grade should be the wheel for best results, and the finer the grain of the wheel, the more highly polished will be the surface produced. In general, for grinding chilled iron a soft or medium soft grade of wheel and a grain of from 60 to 80 will be found satisfactory. For grinding the necks of the rolls, which are not chilled, a wheel of harder grade might be used. The same result may, however, be obtained by speeding up the grinding wheel.

53. Grinding Speeds and Feeds.—The surface speed of the rolls, when grinding, varies from 20 to 60 feet per minute, and the depth of cut varies from .00025 to .004 inch. When grinding hard chilled iron with a depth of cut of .004 inch, the roll is run slowly, at a surface speed of about 20 feet per minute. A traverse speed of the wheel of about 2¼ inches per revolution of the work would be good practice for this case. It is best to use this traverse speed, because by so doing the grinding wheel cuts and consequently wears evenly over almost its entire face. If a lower traverse speed were used, one corner of the wheel would do all the heavy work and the face would be worn out of shape very quickly.

After the roll has been roughed down nearly to size, a cut of .0015 to .002 inch in depth with a traverse speed of about 1 inch per revolution of roll and a surface speed of about 45 feet per minute is taken. When finishing the roll, the surface is run at about 60 feet per minute, the traverse speed is lowered to about ⅛ inch per revolution of work, and cuts of from .00025 to .0005 inch are taken. With a light cut, a high surface speed, and a slow traverse speed, a surface, mirrorlike in appearance, can be ground. A grinding wheel made of alundum, aloxite or adamite, and operating at a surface speed of from 5,500 to 6,500 feet per minute, will give good results.

54. Grinding of Rolls.—When grinding rolls, the necks are ground on the dead centers in the usual manner. The bearings for carrying the rolls are now put on the table of the machine and adjusted to the necks of the rolls, and the tailstock center is adjusted to the work to prevent an endwise movement. A cut is then taken over the roll and the work is calipered on both ends to determine whether the roll is being ground cylindrically. If the roll is found to be smaller at one end than the other, proper adjustment is made and another cut is taken. When grinding, plenty of soda water must be kept running on the part being ground, to avoid burning the surface of the roll.

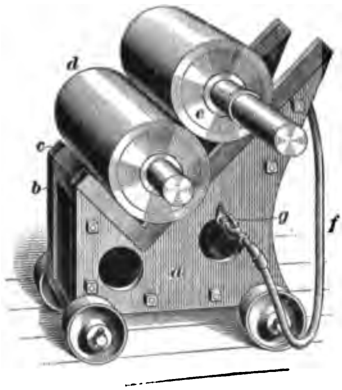


FIG. 25

55. Testing Rolls.—If the rolls are properly ground they should fit perfectly, and in order to test them a chalked straightedge, such as was used to test the straightness of the rolls when turning, may be employed. The arrangement shown in Fig. 25 is sometimes used to test the straightness of the rolls. A small carriage *a* is provided with carefully planed parallels *b* and *c* which are inclined so that the rolls will lie in contact. Two rolls are laid on these parallels, as shown at *d* and *e*. The hose *f* is connected to a gas fixture and a series of gas burners are arranged on the pipe *g* so that they furnish a bright light back of the joint between the rolls. Electric light may be used in place of gas light. If the work has been properly done, no light whatever can be seen between the rolls, as they rest on each other and on the parallels. An extremely delicate test of the accuracy of the workmanship on the rolls is thus given. The straightedge test will usually be found more satisfactory when testing large rolls and the testing device when testing small rolls.

PLANING AND DRILLING CHILLED IRON

56. Tools for Planing Chilled Iron.—It is frequently necessary to plane chilled-iron dies for pressed-brick machines, swage or anvil blocks, drop-hammer dies, guides for rolling mills, and similar purposes. This work may be accomplished by making the speed of the ordinary planer sufficiently slow and the tools sufficiently rigid. Best results are obtained by the use of very rigid machines. In some cases, the planing is done by feeding a broad, square-nosed planing tool directly down on the face of the work, a slight amount of feed being given after each cut. When the width of the tool has been finished, it is moved along and a corresponding cut taken down to the proper depth. This method of procedure is exactly like that employed in turning chilled rolls.

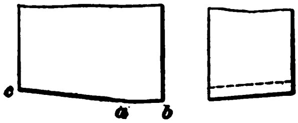


FIG. 26

57. In other cases a fairly broad-nosed planing tool is adjusted so that it will act both as a roughing and a finishing tool and is given a slight feed across the planer after each cut, the cutting edge of the tool being of the general form shown somewhat exaggerated in Fig. 26; the portion *a b* is parallel to the surface of the work to be planed, and the portion *a c* is inclined so that it will act as a roughing tool to prepare the surface for the finishing cut. Such a tool is given a very slight clearance. This practice of feeding sidewise in planing may be followed where it would not be possible to do so in lathe work, because all the feed occurs at the end of the stroke before the tool begins to cut, while in lathe work the tool must be fed sidewise during the cut.

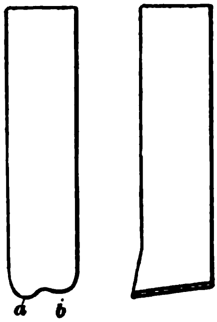


FIG. 27

58. A form of planing tool used only for roughing is shown in Fig. 27. This tool takes two cuts, the parts *a* and *b* doing the cutting. Chilled iron which has been rough-planed with a tool of this form is finished with a broad-nosed tool.

59. Special Forms of Planing Tools.—Chilled rolls are sometimes grooved lengthwise. A tool and holder used to plane grooves of this form is shown in Fig. 28. The tool *a* contains a projection *b* which slides in the slot *c* of the holder *d*. The tool is clamped in any position by means of the yoke *e* and the screw *f*. The sides *g* of the tool are machined to such a shape that the tool, when its face *h* is ground square with the work, will cut a groove of the shape desired. The tool is sharpened by grinding on the face *h* only. The tool holder, yoke, and screw are made of machinery steel, the roughing tool of high-speed steel, and the finishing tool of high-carbon steel.

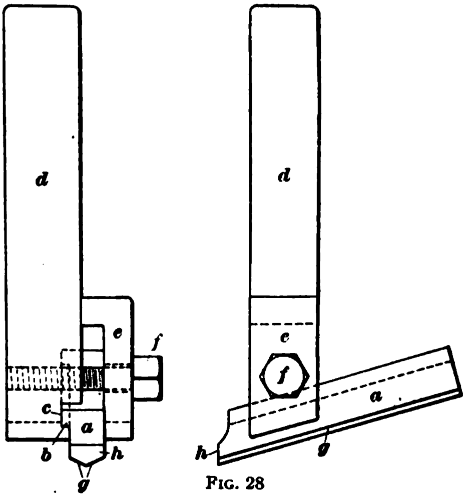


Fig. 28

60. Corrugated Rolls.—Some of the rolls employed in flouring mills must be corrugated after they are turned and ground. The corrugations are shallow grooves planed in the face of the rolls; they are not parallel to the length of the roll, but have a slight spiral. These grooves are found necessary in certain classes of grinding rolls, not only to cause material to feed properly, but to produce the desired result upon the material being ground.

61. Corrugating Machine.—The machine employed for corrugating rolls is similar to a planing machine. One type of this class of machine is illustrated in Fig. 29, in which *a* is the roll being grooved. The weight of the roll is being carried on bearings *b*. The tailstock *c* is provided with a center that prevents any lengthwise movement of the roll, and the headstock *d* is furnished with the necessary mechanism for rotating the roll through the proper angle to give the desired spiral. In the type of machine shown this is accomplished by means of a worm-wheel *e* and a worm *f*. The worm is made long and serves as a rack. It is moved crosswise by the slide *g* traveling in the slot *h*, which may be set at any desired angle with the ways of the machine. The slide carries the worm across the grooving machine as the roll advances, and so rotates the worm-wheel *e* through a portion of a revolution during each stroke of the machine, thus producing a spiral groove. The proper number of divisions or teeth are obtained by means of an automatic spacing device shown on the worm-shaft *i*. This spacing device gives the shaft *i* a portion of a revolution after each stroke of the machine, thus advancing the roll to the next space.

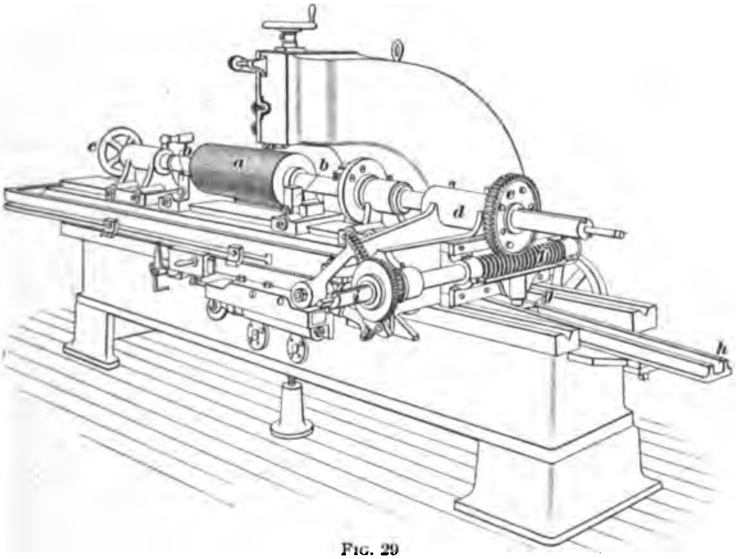


FIG. 29

62. Corrugating the Rolls.—In corrugating rolls, a wide tool similar to that shown in Fig. 30 is employed. This tool is made of $\frac{3}{4}'' \times 1\frac{1}{2}''$ steel. The tool is milled on the end with the kind of corrugation wanted, after which it is hardened. The tool is so set in the machine that it starts to cut on one side and each succeeding tooth takes a deeper cut, until the last one finishes the cut to the required depth. This method may be used if the corrugations are not so large that considerable metal must be removed, when it may be necessary to go around the roll twice to finish the grooves.

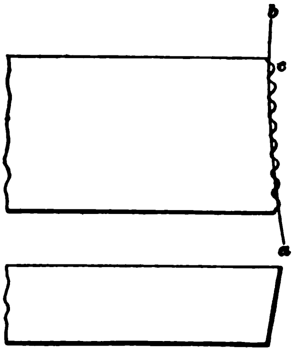


FIG. 30

63. In ordinary practice it is impossible to take a cut of over .015 inch in planing chilled iron, and, unless wide tools with a number of teeth are employed, it will take a very long time to do the corrugating. In Fig. 30 the curved line *a b* represents the circumference of the roll, and each succeeding tooth takes a slightly deeper cut than the preceding, the tooth *c* finishing the groove.

64. Drilling Chilled Iron.—Drills for drilling chilled iron are made of high-carbon steel and of the form shown in Fig. 31. A twist drill would not be strong enough to withstand the hard service. The point of the drill, instead of being ground to the regular angle of drills, is ground very flat, the angle *a* being from 165° to 170°. The tool is carefully hardened and a little clearance is ground on the cutting faces. When drilling, considerable pressure must be applied to the tool, and it must be turned quite slowly. Turpentine is used as a lubricant.

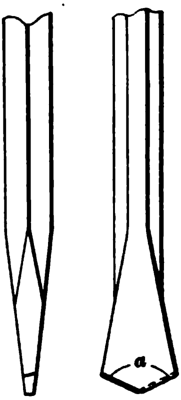


FIG. 31

BENCH, VISE, AND FLOOR WORK

(PART 1)

BENCH AND VISE WORK

1. Explanation of Terms.—The machine-shop operations previously considered have been almost entirely associated with machine tools. Aside from these, a large amount of work is done by hand, such as laying out, chipping, filing, scraping, fitting, etc. These operations are usually performed either on a bench, in a vise, or on the floor, depending on the nature and size or weight of the work; hence, the name *bench, vise, and floor work*.

Bench and vise work is of a lighter nature than floor work, though it may, and often does, include the entire finishing and erecting process where the machine is small, and in the case of large work many of the small parts are assembled at the bench and are then taken to the floor and adjusted to the other parts.

Floor work includes the erecting and assembling of heavy machines and the machining of parts too heavy or too large to be operated on in the stationary machine tools. In the latter case, the heavy parts are set up at a convenient place on the floor and the machining done by means of portable tools set up at a suitable location for each operation.

TOOLS AND FIXTURES EMPLOYED

TOOLS

2. Hammers.—The hammers used by machinists weigh from ¼ to 2 pounds, and are designated as *ball-peen*, *straight-peen*, and *cross-peen*. The ball-peen hammer, weighing from 1

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to 1¾ pounds, and shown in Fig. 1 (*a*), is most commonly used by machinists for all ordinary work, including riveting, and the effect of the blow struck by the ball is equal in all directions. The straight-peen (*b*), and cross-peen (*c*), are employed when the effect of the blow must be greater one way than the other. The smaller sizes of hammers are used on light work.

3. Hammer Handles.—In Fig. 2 (*a*) is shown the form of hammer handle used. The handles vary in length from 10 to 21 inches, depending on the size of the hammer, and are made of the best quality of white, straight-grained, second-growth, well-seasoned hickory. The handle is fitted to the eye in the hammer head so that it fills the eye as nearly as possible. The handle is set at right angles to the head of the hammer, so that when a blow is struck the head will fall squarely.

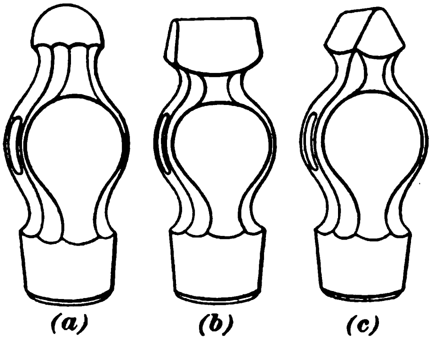


FIG. 1

The eye in the hammer head is made larger at its ends than at the middle, and the handle is wedged in the eye so that it will be held securely in the head. The eye is widened sidewise, or lengthwise, or both sidewise and lengthwise, from the middle of the head toward the outside.

If the widening is sidewise only, one wedge is used as shown at *a*, Fig. 2 (*b*). If the eye is widened at the top and bottom, and not at the sides, two wedges are driven crosswise as shown at *a* in (*c*). If the widening is in both directions, three wedges are used as shown in (*d*). The wedges are made of wrought iron or soft steel.

4. Center and Prick Punches.—Center punches, illustrated in Fig. 3 (*a*), are used to punch the centers of holes to be drilled. The prick punch shown in (*b*) is similar to the center punch, but is smaller. The prick punch is only employed to make the light marks in laying out work, while the center punch is used to make a larger hole and often to move a center hole one way or another. Center and prick punches must have sharp, well-ground points, the angle of the point being about 60°.

5. Special Forms of Center Punches.—Work must sometimes be laid out similar to a model or templet. When this model or templet contains holes that must be similarly located in the work, a center punch as shown in Fig. 3 (*c*) may be used. By putting the cylindrical part *a* of the punch through the holes in the model or templet and striking a blow on the head of the punch, the point *b* is driven into the work. The diameter *c* of the punch must be the same as the diameter of the guide hole in the model or templet.

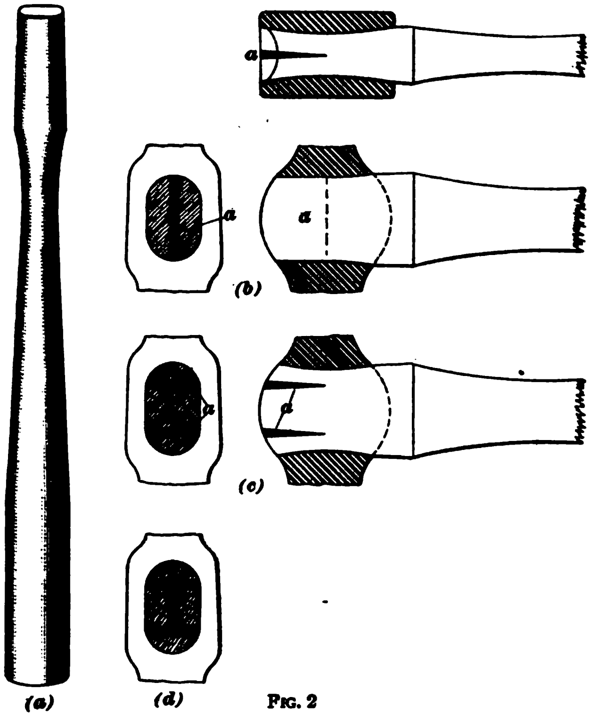


FIG. 2

Holes that are laid out for drilling have a circle drawn to their diameter with a pair of dividers. Where large numbers of these are to be drawn, a tool like that shown in Fig. 3 (*d*) is useful. This may be made from a piece of round steel turned as shown at *a*, making a center punch surrounded by a sharp ring *b*. The point of this tool is placed in the prick-punch mark that shows the center of the hole, and a blow on the head of the tool locates the circle. In some cases, the diameter *b* of the tool is made the same as the diameter of the hole to be drilled, though for some work it is made larger than the hole and shows whether the work has been properly drilled.

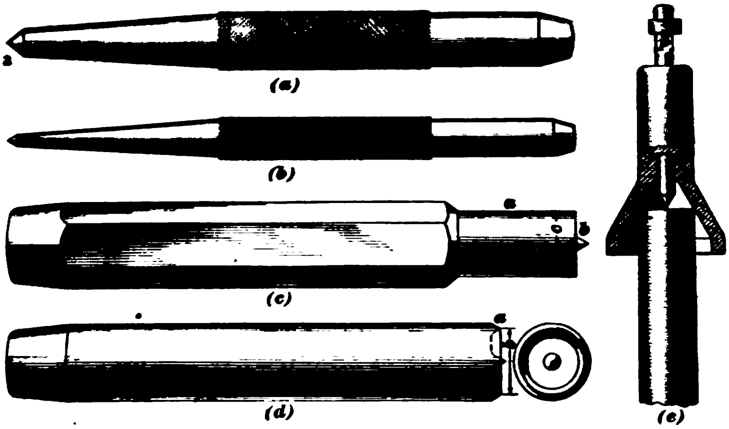
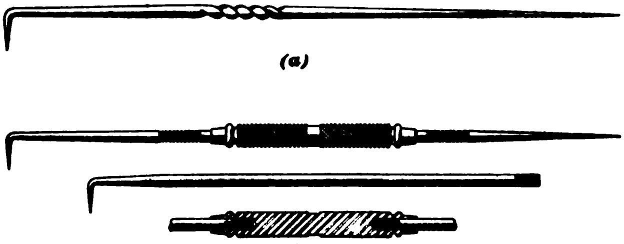


FIG. 3

A form of centering tool, known as a cup center and shown in Fig. 3 (*e*), is sometimes used for centering round work. When the tool is placed on the work as shown and a blow is struck on the pin *p*, the point is driven into the center of the work.

6. Scribers.—One form of scriber in common use, shown in Fig. 4 (*a*), may be made of a piece of $\frac{3}{16}$-inch steel wire, from 6 to 10 inches long. It is twisted in the middle so as to be easily held in the hand, and one end is bent at right angles to the main part. The points are ground sharp and the scriber is hardened and tempered. It is used for drawing lines in laying out work. One form of improved scriber with nurled handles and inserted scribing points is shown in Fig. 4 (*b*).

7. Bench Centers and Straightening Press.—The bench centers illustrated in Fig. 5 are for the convenience of the viseman in centering work for the lathe. The centers *a* and *b*


(a)

(b)

Fig. 4

may be set at any location along the rod *c*. The head *d* is provided with either a spring or a screw center, so that the piece can easily be put in place or removed.

The piece to be centered is put in the vise, center-punched, put in the bench center, and rotated to show whether it runs out, and how much. The side out of center is marked with chalk, and the center hole drawn toward that side with the center punch. This operation must be repeated until the piece runs true enough to finish. If the middle of the piece is out of true or is crooked, it should be straightened by hammering or by bending in the screw-straightening press *e*, back of the centers. The straightening press consists of two movable **V** blocks *f* resting on a base *g*, and a screw *h* with a **V** point on the lower end, the screw being supported in a frame, as shown. To straighten a piece, it is laid upon the blocks *f*, with the bend up, and the screw lowered until the bend is removed.

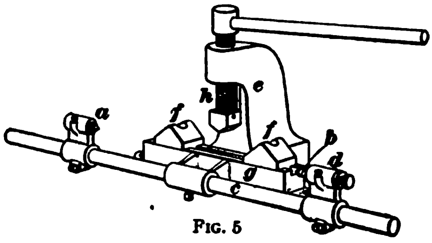


Fig. 5

8. Hand Hack Saws.—The hack saw consists of a frame and blade. Some of the frames are made to employ one size of blade only, while others are made to use blades of two or three different lengths. The hack-saw blades are made in lengths of from 6 to 36 inches, and may be used either in hand frames or in specially designed power machines.

The hand frame illustrated in Fig. 6 (*a*) is an adjustable frame in which blades from 8 to 12 inches long can be used. The clamps holding the ends of the blade may be set in four positions, which allow the saw to be operated in any desired direction. Fig. 6 (*b*) shows the blade set at right angles to the plane of the frame to cut lengthwise of the piece. In hand work, the operator should raise the frame slightly when drawing the saw back; otherwise, the back stroke is destructive to the teeth.

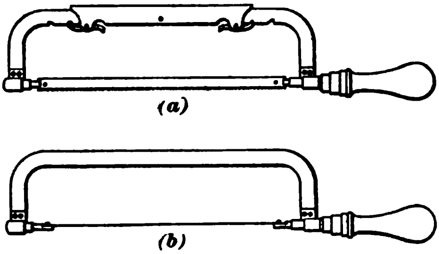


FIG. 6

9. Power Hack Saw.—A power hack saw is illustrated in Fig. 7. It is provided with a vise for holding the stock to be cut off, and is made to stop automatically when the piece is cut through. The blades used in the machine are generally 12 or more inches long; they will cut stock as large as 4 inches in diameter. The power saw has a great advantage over the cutting-off machine, in that it will cut stock of any irregular section. It is especially adapted to cutting off tool steel, which it does quickly, with very slight waste. The saw frame of this machine has an upward motion during the back stroke that lifts the teeth off the piece being sawed, thus saving the points of the teeth.

10. Hack-saw blades are so hard that they cannot be filed, and are thrown away when dull. They are made with about 25 teeth per inch for sawing thin metal, brass tubing, and pipe, and with about 14 teeth per inch for other work. The 8-, 10-, and 12-inch blades used in hand frames are about $\frac{25}{1000}$ inch thick and $\frac{1}{2}$ inch wide. Longer blades are generally used in the power-driven hack saw than in the hand hack saw, as in the power machine the blade is guided uniformly in a straight line, whereas in the hand hack saw the blade is likely to run unevenly, and so be cramped and broken. The blade commonly employed in the machine has about 12 teeth to the inch, is about $\frac{3}{100}$ inch thick, and $\frac{5}{8}$ inch wide.

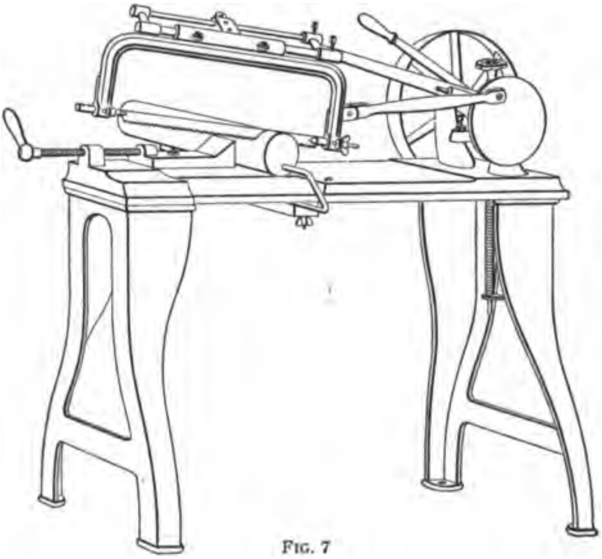


FIG. 7

Hack-saw blades, while very hard, have a fair amount of elasticity; 10-inch blades of the best makes may be bent to a half circle without breaking.

WRENCHES

11. Single-End Wrenches.—Two classes of single-end wrenches are manufactured. An *open-end wrench* is one that encloses three sides of a square, or four sides of a hexagonal nut or head; a *closed-end wrench* is one that entirely surrounds the nut or head. Open-end wrenches have certain advantages, in that they need not be slipped over the end of the bolt or nut;

they are made both with the sides of the jaws parallel to the line of the handle and with the sides of the jaws set at an angle to the center line of the handle.

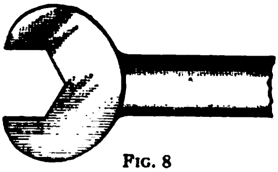


FIG. 8

12. For some purposes the **straight single-end wrench** with the sides of the jaws parallel to the handle, as illustrated in Fig. 8, is suitable; but for work in contracted spaces an **offset wrench** is more convenient. The offset should be 15°. The manner of using the wrench is illustrated in the four views in Fig. 9. The wrench handle *b* operates between the obstructions *c* and *d*. The wrench is first placed on the nut *f* as shown in (*a*), and the handle moved to the left into the position shown in (*b*). The wrench is then turned over and placed on the nut, as illustrated in (*c*), when it may be given another movement, bringing it into the position shown

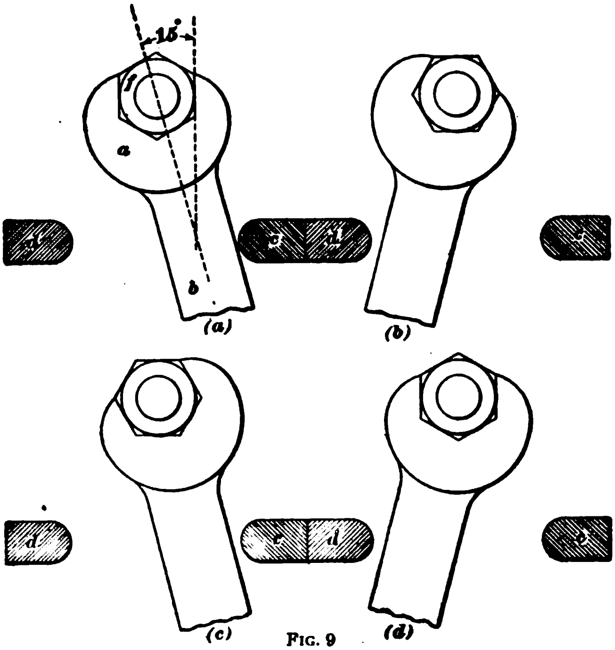


FIG. 9

in (*d*). The nut will have been advanced $\frac{1}{6}$ of a turn in 2 moves; therefore, 12 movements are necessary to make a complete turn. If the wrench were made straight, as shown in Fig. 8, it could not be operated in the manner illustrated in Fig. 9, and the nut would have to be so located as to allow a clear space in which the wrench could make $\frac{1}{6}$ of a turn.

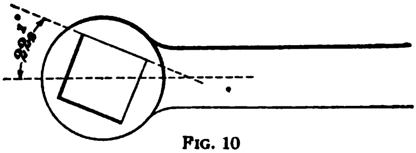


FIG. 10

13. The open-end wrench is especially adapted for screwing on nuts, screwing in cap bolts, etc.; but for operating taps and other work, a **closed-end wrench** similar to that shown in Fig. 10 is often used. The sides of the jaws may be made parallel to the handle, as shown in Fig. 8, or offset, as shown in Fig. 9. If the wrench is intended for a square-end tap, the offset should be one-half of 45°, or $22\frac{1}{2}°$, as shown in Fig. 10. This will enable the operator to advance the tap $\frac{1}{8}$ of a turn in case there are obstructions so placed that it is impossible to make a greater fraction of a turn.

14. Double-End Wrench.—The wrenches used for turning taps and hand reamers are made in several forms. Some are made solid, with one or more holes for different-sized shanks; but the wrenches most commonly used are made of the form shown in Fig. 11. This wrench is adjustable to several different sizes of tap squares. The length of the handles of different wrenches of this type are proportionate to the diameters of the taps on which they are to be used. Holes must frequently be tapped in spaces where wrenches of this type cannot be turned, and the single-end wrench must be substituted; but, where practicable, an extension should be placed on the tap and a double-end wrench employed, as by this means holes

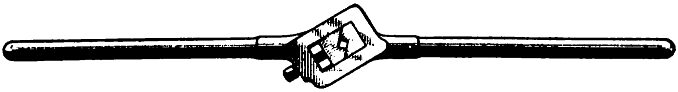
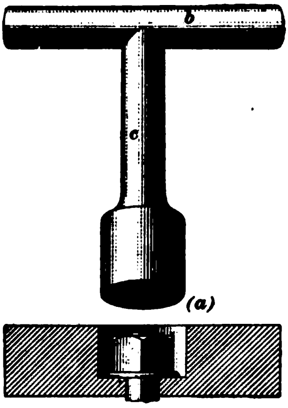


FIG. 11

can be tapped more nearly true and the danger of breaking the tap is less.

15. **Socket Wrenches.**—The most common form of socket wrench is illustrated in Fig. 12 (*a*). It is used to turn nuts and bolt heads set in recesses below the surface of the work, as shown in (*b*). These wrenches are made with either square or hexagonal sockets, as the work may require. The sockets are made by laying out the desired form on the end, drilling one or more holes to remove the majority of the stock—in the case of a large wrench, chipping out some of the remainder of the stock, and then broaching the hole to the desired form.



(*a*)

(*b*)

FIG. 12

16. When it becomes necessary to tap holes or to screw in studs or bolts in contracted spaces, the work may sometimes be reached by means of a **socket extension** similar to that shown in Fig. 13. This consists simply of a long stem *a* having at one end a socket *c*, of the form required to fit the work, and a square *b* on the other end intended to fit a single- or double-end wrench. Usually, these socket extensions are used only with double-end wrenches.

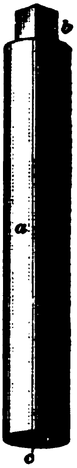


FIG. 13

17. **Ratchet Wrenches.**—With practically all single-end wrenches, the wrench must be removed and replaced on the nut after a portion of a turn has been made. As there are a great many places where only a single-end wrench can be used, much time is lost in changing the wrench. To prevent this, ratchet wrenches are employed. In one form of adjustable ratchet wrench, illustrated in Fig. 14, the jaws *a* can be so adjusted by means of the screws *b* that they will accommodate a number

of sizes. A handle *c* can be moved forwards through whatever portion of a stroke the location will permit, and then return for another stroke. Even as little as one tooth *d* of the ratchet may be moved. This style of ratchet wrench has but a single pawl engaging the ratchet, and hence there will be some lost motion before the pawl engages a tooth on the forward stroke.

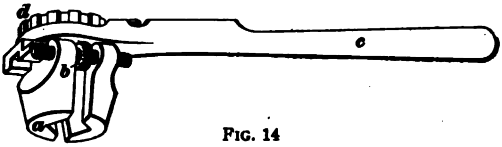


FIG. 14

18. The teeth of the ratchet should be as coarse as possible, to give them the requisite strength. Then, in order to get the least amount of lost motion, the multiple-pawl ratchet is used. This form is illustrated in Fig. 15, in which the ratchet *a* has 12 teeth; 5 pawls *b* are so placed that only one of them will engage a tooth at a time, as shown at *c*. By moving the pawls back $\frac{1}{5}$ of a space between the teeth, the next pawl will come in contact as at *d*, and hence the lost motion cannot be greater

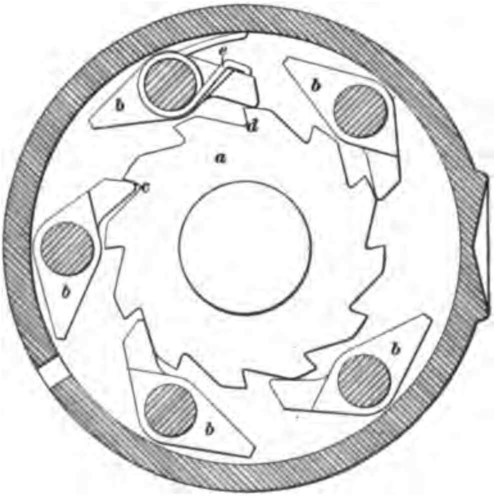


FIG. 15

than $\frac{1}{8}$ of, $\frac{1}{16}$ or $\frac{1}{32}$, of a turn. The pawls are kept in contact with the ratchet by springs, as shown at *e*.

19. Studbolt Wrench.—For driving studs by means of a ratchet, a special stud holder, shown in Fig. 16, is provided. The stud *a* is screwed into the socket *b*, and then the point of the setscrew *c* is run down against the end of the stud so as to lock it in the socket. The setscrew *c* is held in place by means of a locknut *d* and the stud driver is operated by means of a ratchet *c'* on the square *e*.

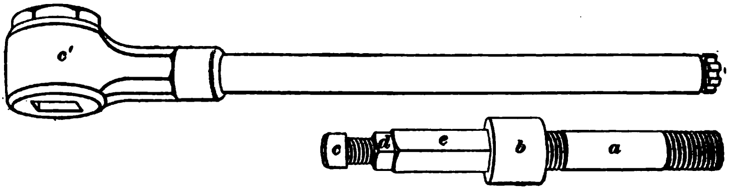


FIG. 16

Ratchets may be applied also to socket extension wrenches where these are in locations in which a complete turn cannot be made.

20. Pipe Tongs.—Iron pipe is screwed together with wrenches of various forms, some of which are shown in the following illustrations: Fig. 17 shows the most common form, commonly called *pipe tongs*, one size being provided for each separate size of pipe. This general style is also made with the jaw *a* adjustable and controlled by a screw, so as to adapt one pair of tongs to several sizes of pipe.

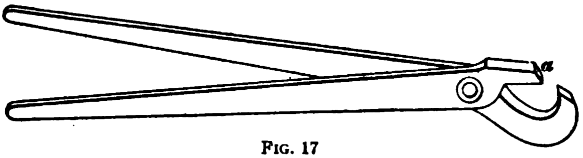


FIG. 17

The *chain tongs* shown in Fig. 18 is especially adapted to work on large pipe. The handle *e* has two steel jaws *a* cut on both sides. A chain *b* made fast to the bolt *c* permits both sides of the jaws to be used. The tongs are rotated in the direction of the arrow. Tongs of this type are made of various sizes for use on all sizes of pipe. Chain tongs are the most rapid tools of their kind for medium and large work.

21. Pipe Wrenches.—The *Stillson pipe wrench*, illustrated in Fig. 19, is an adjustable wrench. It has a movable jaw *a* moved by the milled nut *b*, and may be used on several sizes. Although made particularly for pipework, it finds many other useful applications. When in use, the wrench is turned in the direction of the arrow. *Alligator wrenches* have a **V**-shaped opening in one end, and in the smaller sizes in both ends. One side of this opening is left smooth and the other has teeth cut across it in the form shown in Fig. 20. These wrenches grip all round objects, and are used to grip pipe in places where the other forms of wrenches can get no hold at all.

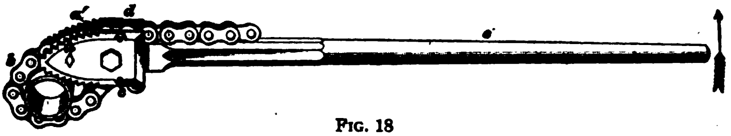


FIG. 18

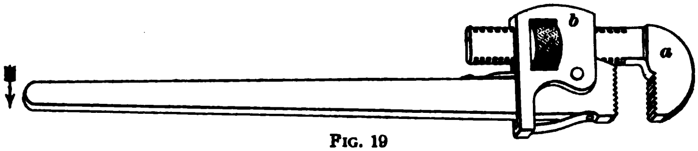


FIG. 19

22. Monkeywrench and Pipe Attachments.—In Fig. 21 are shown a monkeywrench and its attachments. The wrench is adjustable and is much used in the machine shop. When in use, it is rotated in the direction of the arrow. A wedge-shaped piece of steel, or false jaw, having teeth cut on it similar to those on the jaw of an alligator wrench, may be made for any size of monkeywrench. When supplied with this

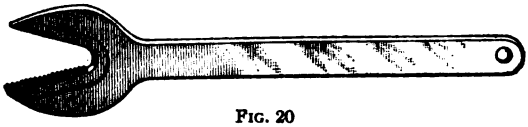


FIG. 20

false jaw, the monkeywrench is used for pipe work. Such a jaw *b* is shown attached to the wrench in (*a*). This jaw is made with but one arm bent at a right angle, as shown in (*b*),

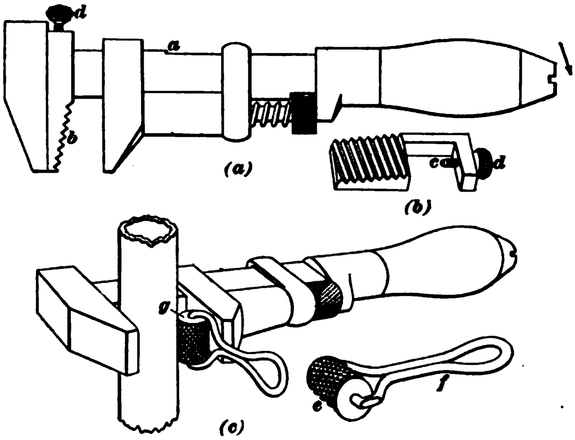


FIG. 21

to pass over the back of the bar. A thumbscrew *d* is used to hold the jaw on the bar. Instead of the form of false jaw just described, one made in the form of a fork whose two arms reach past the bar *a* in (*a*), of the wrench may be used. A hole is drilled through the ends of this jaw, so that a split pin can be put through them to keep the jaw from falling from its place on the bar. Another simple attachment for adapting a monkey-wrench to pipework is shown in (*c*). This device consists of a

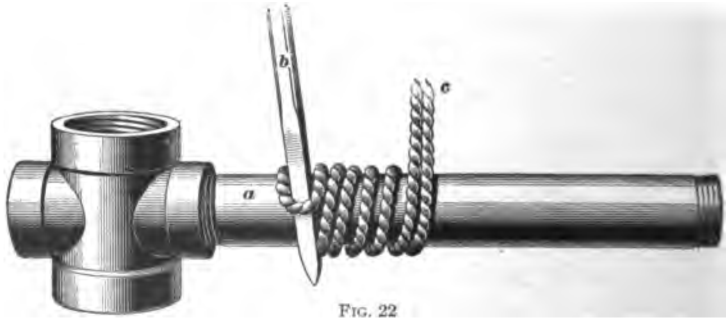


FIG. 22

nurled and hardened cylinder, or roller, *e*, having a wire handle *f* for convenience in putting it in place. It is set between the wrench jaw and the pipe, or other round piece, as shown at *g*. A piece of a 10- or 12-inch round file about 1 or 1½ inches long may be used instead of this attachment.

23. **Use of Rope as Pipe Wrench.**—A rope may be used in place of a pipe wrench in the manner shown in Fig. 22. The rope is first doubled, as shown at *a*, and given enough turns round the pipe to insure gripping. A bar or a piece of wood *b* is thrust through the double end of the rope *a*, and the two loose ends *c* of the rope are brought together and held with one hand while the other hand is applied to the bar. Enough strain is put on *c* to prevent slipping, and the pipe is turned by the bar *b*, the same as with any pipe wrench. The workman may walk around the pipe, or by slacking off on both the bar and the rope ends, he may rotate the rope backwards to get a new hold.

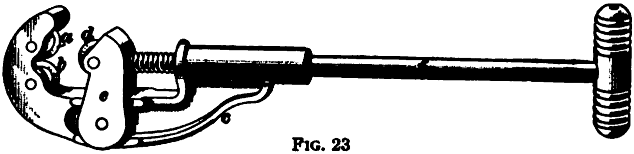


FIG. 23

24. **Pipe Cutter.**—Large pipe is generally cut into the proper lengths in a pipe-cutting machine by a cutting-off tool, in the same manner as stock is cut off in the lathe, and afterwards is threaded in the same machine. Some pipe machines are driven by hand, others by power. A great deal of small pipe is cut with a pipe cutter, shown in Fig. 23. The body *c* of this tool carries a slide *e*, operated by the screw on the handle *f*. Three hardened-steel cutting wheels *a*, *b*, *d* are set in the frame and slide. The slide *e* is drawn back by means of the screw, to allow the pipe to pass between the cutters, which are then forced into the pipe by turning the handle *f*, and at the same time rotating the tool around the pipe. Other cutters of this sort have but one cutting wheel, which is in the slide. In this case the wheels *a* and *b* are replaced by

cylindrical rollers and the wheel *d* by a narrow cutting-off tool. A hack saw makes a good pipe cutter, if employed carefully, and when blades having 25 teeth per inch are used, there is little danger of breakage. Thin brass and copper tubing can be cut more easily by a hack saw than by any other means.

VISES

25. Purpose of Vises.—In the machine shop a large amount of work is necessarily done by hand, and holding and clamping devices of various sorts are required for pieces that are not so heavy that their own weight will give them the necessary stability. The *parallel jaw vise* will hold nearly all flat pieces, and special jaws or devices are made for holding irregular and special forms.

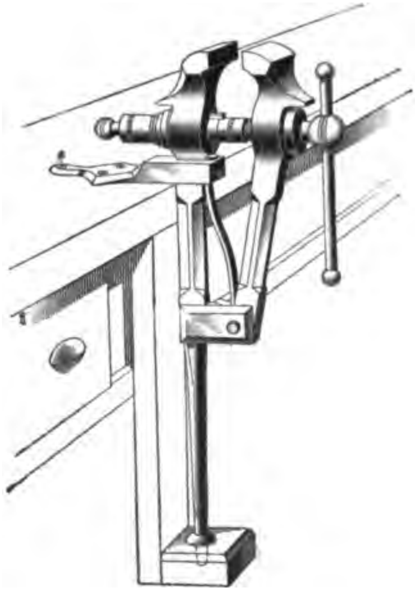


FIG. 24

26. Screw Vise.—In Fig. 24 is illustrated a heavy form of ironworker's vise designed for the largest, heaviest, and roughest class of work. The jaws are made as large as 8 inches wide and are operated by the screw, which requires considerable time for its manipulation. The body is secured to the bench with bolts that pass through the strap *s*. Where a vise must be operated frequently or through a considerable portion of its jaw traverse, some special provision for a more rapid traverse of the jaw must be made.

27. Rapid-Motion Vise.—In Fig. 25 is an illustration of a vise so constructed that the operator simply pushes the cam handle *a* away from him with his right hand, and thus releases the work and allows the movable jaw *b* to be rapidly pushed or pulled into any position. The work is placed between the jaws and gripped by a pull on the lever.

28. Swivel Vise.—In the tool room and in many places where light or fine work is done, a screw vise like that shown in Fig. 26 is frequently used. This vise is made in various sizes up to those with 7-inch jaws. A common size of this form is one with a jaw $2\frac{5}{8}$ inches wide. The back jaw *a* is hinged and held parallel with the front jaw by a taper pin *b*, as shown. Wedge-shaped pieces must often be held and for this work the pin *b* is removed and the pressure of the fixed jaw against the work rotates the movable jaw to conform to the piece held. This vise is also provided with a base piece *c*, which is bolted fast to the bench. The vise proper is swiveled on this base and held in different positions by the pin *d*, which is drawn up to release the vise and dropped into one of a series of holes in the base when the vise is in the proper position.

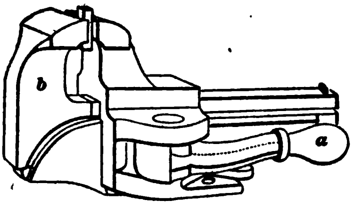


FIG. 25

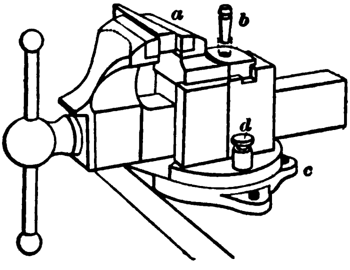


FIG. 26

29. Pipe Vise.—The pipe vise is a special form of tool made for firmly gripping pipe or other hollow pieces that would be crushed if gripped in the ordinary vise. Fig. 27 illustrates one of the best forms of vise for this class of work. The pipe is gripped between two jaws *a*, *a′* held in a malleable-iron frame with a movable top *d* hinged at *e*. When in use, the free side of the top *d* is held in place by the pin *f*. The hinged top on this vise allows fittings to be screwed to both ends of a piece of pipe, and then, by simply withdrawing the pin *f*, the whole top of the vise may be thrown back clear of the work, which can be lifted out instead of being pulled through the jaws.

30. Pipe, being round, cannot be screwed together by the ordinary forms of wrenches, and, being hollow, it cannot be held in the ordinary vise without being crushed. For cutting, threading, or having fittings screwed on it, pipe may be held in the pipe vise just described, or in an ordinary vise having clamps made in the form shown in Fig. 28. The holes *a* in this clamp are made to fit the outside diameter of the pipe, and have teeth cut in them to prevent the work from slipping. They are held together by the spring *b*. For putting polished pipe together, some form of clamp or wrench having smooth jaws must be used.

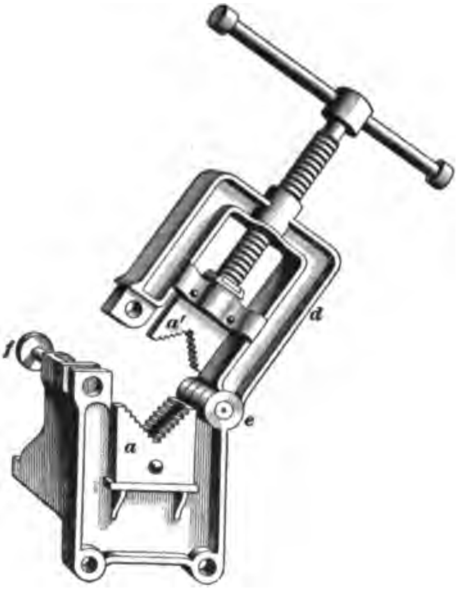


FIG. 27

31. Vise Jaws.—All the vises illustrated are made of cast iron, except the pipe vise, which is made of malleable iron.

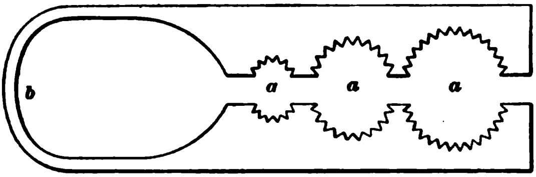


FIG. 28

These materials make poor gripping surfaces, so the jaws are covered with welded or riveted steel faces having cross-cuts on them, in order to grip the work more firmly. A piece of finished work gripped with the surfaced jaws would be seriously marred. In Fig. 29 is shown a pair of soft-metal vise jaws made to fit over the steel jaws of the vise. When finished work is gripped between these jaws it is not marred. They are usually made of sheet copper from $\frac{1}{32}$ to $\frac{1}{16}$ inch thick.

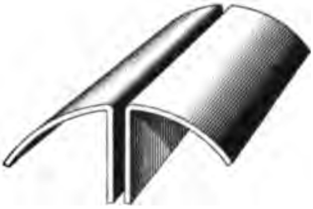


FIG. 29

Special jaws having cylindrical or irregular recesses cut in them to receive special work are sometimes used. When these jaws are faced with vulcanized paper or leather, finely polished brass or nickeled pipe and similar work may be held without marring the finish.

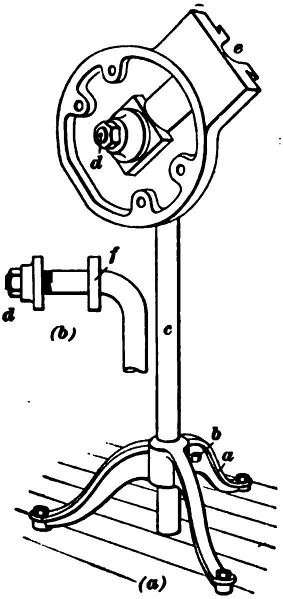


FIG. 30

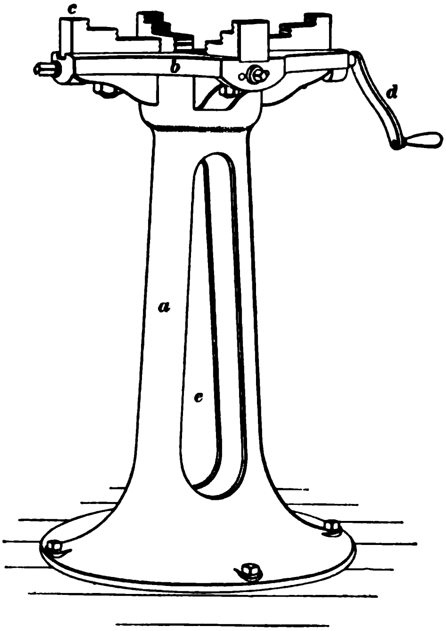


FIG. 31

32. Special forms of vises are often made for holding work of such form as is inconvenient to hold in the common vise.

An example of this class of tool is the **filing stand** shown in Fig. 30 (*a*), which is a fixture for holding the swivel slide of a planer head while the edges are being finished. This vise, or holder, consists of a three-legged base *a*, screwed to the floor, and an upright *c*, supported by the base, that may be clamped in any desired position by the setscrew *b*. The top of the upright is bent at right angles to *c* and threaded for the nut *d*, which clamps the work *e* against the solid collar *f*, as shown in the detail view (*b*).

33. The **reaming stand,** Fig. 31, is another form of special vise, consisting of an upright *a* and a top *b*, which carries four jaws *c* operated by the handle *d*. This stand is bolted to the floor and has an opening *e* in the column, so that tools may be run clear through the work and removed at the bottom. Pulleys, gears, and similar pieces may be held for hand reaming and work may also be held for tapping. A similar and, for some purposes, more convenient form of reaming stand is made by fastening a four-jaw combination or universal chuck on an upright. The universal chuck has the advantage that for many small pieces only one screw need be moved to open or close the jaws.

BENCHES

34. Forms of Benches.—A very important part of the equipment of a shop consists of the benches, especially where a large amount of light work is done. They are usually made from 30 to 36 inches high, depending on the character of the work, the lighter work being done on the higher benches.

The forms of benches vary greatly, some being made stationary and others portable. The bench must, however, always have provision for attaching a vise, without which a machinist's work bench is incomplete. For this reason they are frequently called *vise benches*.

35. General Arrangement of Benches.—The vise bench should be located along the side of the room having the best light. The north side of the building is the best location for the bench, because the light is more even at all hours of the day. The main features of the bench must, of course, be governed by the work to be done; but it should always be convenient, clean, and rigid. In many shops the bench is made with wooden uprights fastened to both the wall and the floor, and a hardwood top, which is 2 inches thick for a bench for light work, and from 3 to 4 inches thick for a bench for heavy work. The front of the bench gets the hardest usage, and the back half of the top may be made much thinner. Vises suitable for the work to be done should be located at convenient distances apart, and for each vise there should be one or more drawers, each provided with a lock and arranged to hold conveniently such tools as the workman may require. Sometimes a tier of drawers is put in instead of the single one, while at other times cupboards are preferred. Cupboards, however, take up much room and hold conparatively little, and for this reason the drawers are usually more desirable.

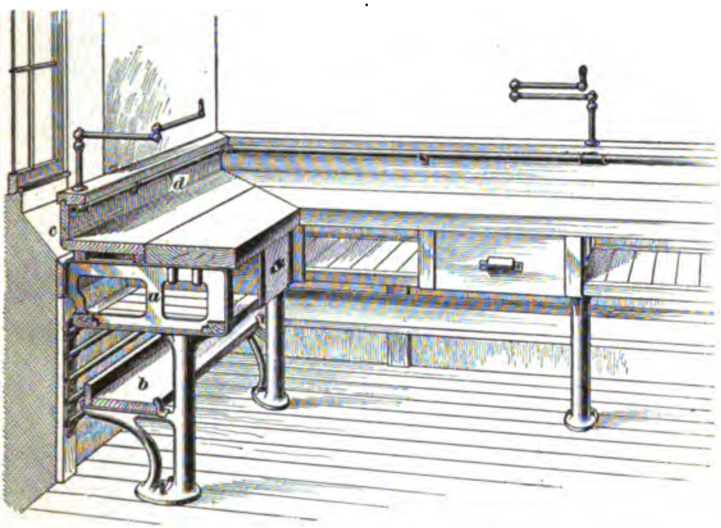


FIG. 32

36. Bench With Cast-Iron Legs and Frame.—The best form of bench for general use is that illustrated in Fig. 32. A cast support *a* is bolted to the floor and also to the wall.

The lower part has a bracket for carrying a shelf *b* that extends the whole length of the bench, while provision is made under the top for alternate drawers and shelves. Provision is also made in each support by which the bolt holding the vise passes through the casting and thus secures the vise in the most rigid position. The shelf near the bottom allows ample room for

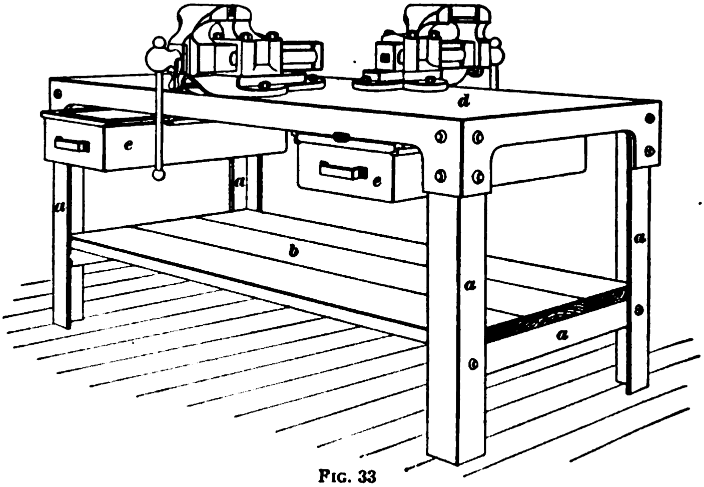


FIG. 33

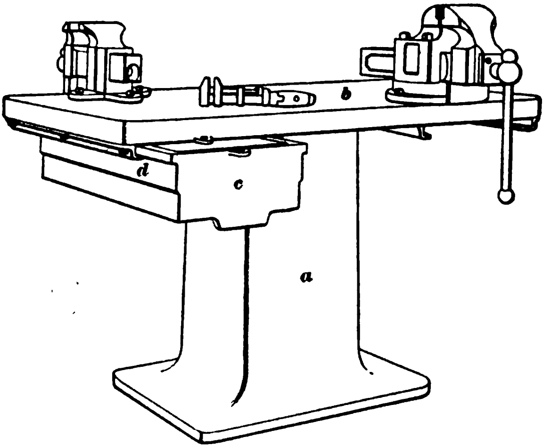


FIG. 34

the sweeper to get his broom clear to the wall. The top of the bench should have a smooth finish and all the visible woodwork should be varnished with good shellac. The bench is thus made much easier to keep neat and clean. If the shop is heated by steam, the pipes may be placed under the bench and openings *c* provided before the windows. This insures a rising current of warm air past the window and so protects the workman from cold drafts. In the form shown, a gas pipe *d* extends along the back of the bench. When the shop is lighted by electricity, the gas pipe is replaced by an electric conduit.

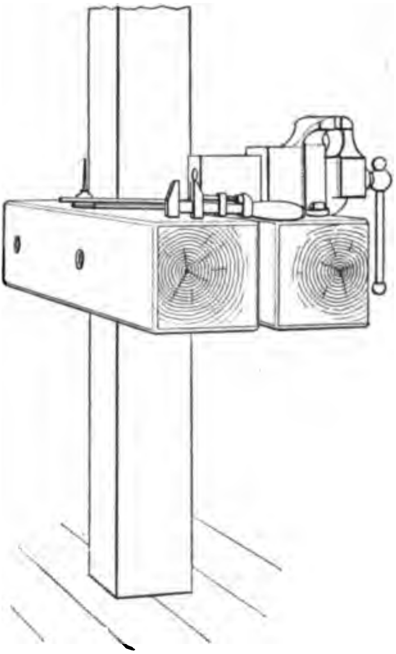


FIG. 35

37. Portable Benches. Examples of good types of portable benches are shown in Figs. 33 and 34. The larger of these, Fig. 33, consists of angle-iron legs *a* carrying a wooden shelf *b* and a cast-iron top *d* that may be planed true and used as a laying-out table. The bench is provided with two vises and drawers *e*, for tools. This bench may be moved to the work, instead of taking the work to the bench, which makes it especially useful in large shops where heavy machinery is erected. When engines or other machines are shipped, the bench is often loaded on the cars as one of the erecting tools, and is returned to the shop when the work is finished.

The bench illustrated in Fig. 34 consists of a cast-iron column *a* and a cast-iron top *b* provided with two vises. The bench may be used without the vises for a small laying-out table. A cast drawer *c* held by gibs *d* provides a convenient place for the tools used by the workman. This bench is easily moved to any part of the shop and occupies but little space.

38. Post Bench.—Fig. 35 shows a convenient form of bench that may easily be constructed from two pieces of timber cut to fit a post or column and fastened in position with two bolts. It is useful principally as a vise bench, as shown, but may be used for a variety of purposes.

CHIPPING AND FILING

CHIPPING

39. Forms of Chisels.—The forms of chisels most commonly used in the machine shop are the *flat*, *cape*, *diamond*, *grooving*, and *side* chisels, and the *gouge*. They are generally made from octagon steel of the size most convenient for the work for which they are to be used. Special grades of steel, known as *chisel steel* and containing about 1 per cent. of carbon, are made for chisels.

The proper cutting angle for most chisels is the same as that for the flat chisel for metals of the same grade, the angles for different grades of metal varying from 50° to 75°. The softer the metal, the sharper the cutting angle of the chisel should be.

When cold chisels are used in the pneumatic hammer, the shanks must be fitted to the holder in the hammer, either by turning or milling, and the head should be carefully tempered to prevent its being upset in the socket of the machine. The chisels used in the pneumatic machine should be longer than those used by hand.

40. The **flat chisel** is the one most generally used; it is made in the forms shown in Fig. 36 (*a*), (*b*), and (*c*). The width of the cutting edge should, if possible, be proportioned to the hardness of the metal on which it is to be used, a narrow chisel being used for chipping the harder metals. If one width of chisel must answer for brass, cast iron, steel, and Babbitt, lighter blows should be struck while cutting the softer metals, or the metal will be broken rather than cut off by the chisel. A chisel about 1 inch in width is ordinarily used for general purposes.

41. For finishing surfaces, the edge of the flat chisel should be ground square, as shown in Fig. 36 (*a*), the best angle for

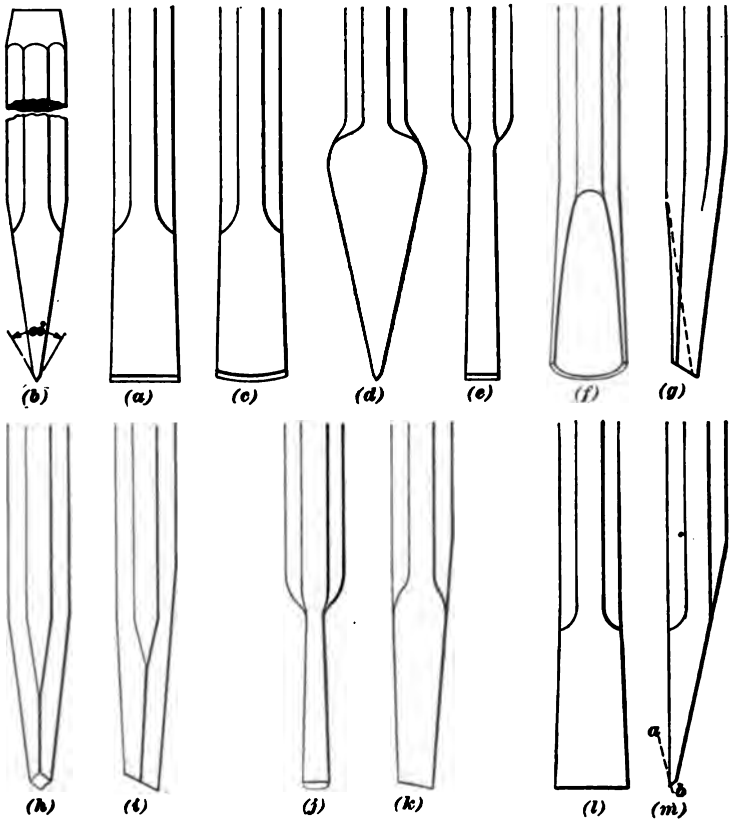


FIG. 36

ordinary work being about 60°, as shown in (*b*). This angle may, however, vary between about 50° and 75°, depending on the hardness of the material to be chipped, the blunter angle being used for the harder metals. Chisels ground with square corners, as illustrated in (*a*), are likely to have the corners broken when used for heavy work; but this can be sometimes prevented by grinding the chisel slightly rounding, as shown in (*c*).

42. The **cape chisel,** which is shown in Fig. 36 (*d*) and (*e*), is used for making narrow grooves, and is manufactured in widths to correspond to the widths of the grooves to be cut; for general work it may be from ⅜ to ½ inch wide. This chisel should be made wider at the cutting edge than it is farther back, to provide side clearance. The chisel will then work easier and will not break out the edges of the groove. Where a large surface is to be finished by chipping, it is customary to cut a number of grooves across it with the cape chisel and then use a flat chisel to remove the stock left between the grooves.

43. The **half-round gouge,** shown in Fig. 36 (*f*) and (*g*), is for work on rounded surfaces or fillets, or for cutting half-round grooves.

44. The **diamond-point chisel,** shown in Fig. 36 (*h*) and (*i*), is used for V-shaped grooves or for finishing out corners. It is largely used with a very light hammer in lettering bottle molds, for which use it is made of ⅜-inch steel.

45. The **grooving chisel,** Fig. 36 (*j*) and (*k*), is used for chipping oil grooves and similar work, and is often made of extra length to reach through long hubs. This chisel should be made wider at its cutting edge than it is farther back, as in the case of the cape chisel; otherwise, it may leave a burr on the edges of the groove.

46. The **side chisel,** shown in Fig. 36 (*l*) and (*m*), is used for finishing the sides of slots and similar work. The chisel is ground straight on the side next to the work, if it is to be used in deep holes; for shallow holes it is best to give it a slight angle, as indicated by the line *a b*, (*m*), and to allow the body of the chisel to stand at a greater angle to the work while being used.

47. Methods of Chipping.—*Chipping* is the process of removing stock by means of the hammer and chisel. It corresponds to the roughing cut in machine tool work, and the filing that follows it takes the place of the finishing cut.

There are two methods of chipping—the *hand* and the *pneumatic*. The process is applied both to the roughest and coarsest work, and to some of the finest work that comes to the machinist. It is used in the machine shop, foundry, and smith shop, and chisels of various sorts form an important part of the outfit of the erecting gang.

48. Holding Hammer and Chisel.—For ordinary chipping, a hammer weighing from 1 to 1¾ pounds, and a variety of chisels, the most common of which are the flat, cape, gouge, and various forms of side and grooving chisels, are used. When chipping, the hammer is held in the right hand, as shown in Fig. 37, and is grasped by the thumb and second and third fingers, the first and fourth fingers being closed loosely around it. The hammer handle may thus be swung more steadily and more freely without tiring the hand so much as if the handle were grasped rigidly by all four fingers.

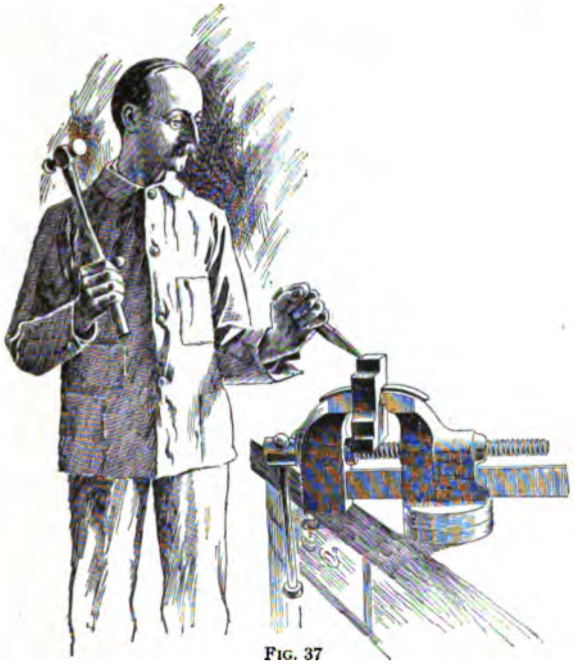


FIG. 37

49. The chisel should be grasped in the left hand with the head close to the thumb and first finger, and held firmly with the second and third fingers; the little finger may be used to guide the tool as may be required. The first finger and the thumb should be left slack, as they are then in a state of rest, with the muscles relaxed, and are less liable to be injured if struck with the hammer than if they were closed rigidly about the chisel. The point of the chisel is held on the work, as shown in Fig. 37, at the place where it is desired to take the cut, and at an angle that will cause the cutting edge to follow the desired finished surface. After each blow the chisel is set to the proper position for the next cut. The depth of the cut depends on the angle at which the chisel is held to the work. When the angle between the work and the chisel is increased, the chisel will cut deeper and when decreased the chisel will remove less metal.

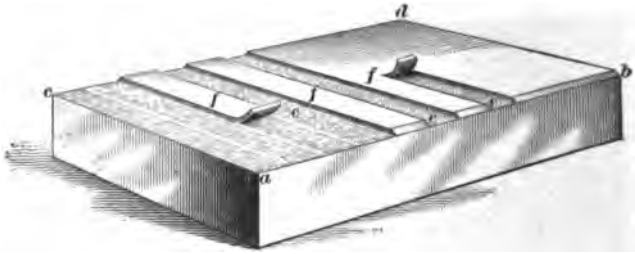


FIG. 38

50. Chipping Large Flat Surfaces.—Large surfaces, whether flat or curved, are sometimes finished by chipping. The piece is laid out as shown in Fig. 38, the lines *a b*, *a c*, etc. outlining the edges of the required surface. To facilitate the starting of the chisel and to prevent the breaking off of the stock as the chisel leaves the work, it is well to chamfer the front and back edges, as shown at *a b* and *c d*. The stock above the lines *a b*, *c d*, etc. is removed by first cutting grooves *e* across the surface, leaving the ridges *f* between. These ridges are subsequently removed with a flat chisel. In the illustration, the left-hand ridge has all been removed and half of the one next to it. By cutting the grooves across with the cape chisel. the work of the flat chisel is much reduced, as it is used only for straight cutting with no tearing or lifting of the metal at the corners. The width of the ridges *f* is determined by the width of the flat chisel to be employed, and should be as great as the character of the material being cut will permit.

51. **Chipping Strip.**—The castings for many kinds of work are frequently fitted by chipping and filing. Work of this class has what is called a chipping strip on the casting wherever fitting is to be done. This strip is $\frac{1}{8}$ inch or more higher than the body of the casting, and wide enough to make the joint or fit. Castings to be fitted by this process are put together and their high spots noted, chalked, and chipped off. As the work progresses and the heavier parts are removed, red marking is rubbed on the work, and the parts are tried or rubbed together. The coating of red will be rubbed off on the spots that come in contact with the other part, thus showing more plainly where the chipping must be done. When

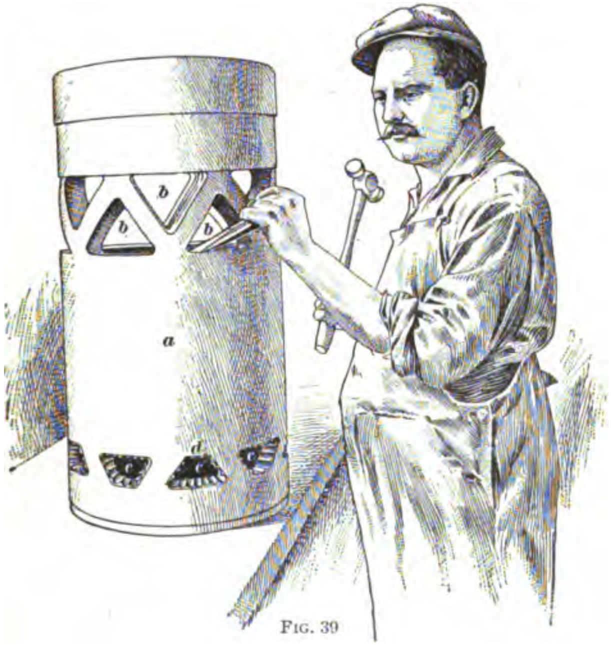
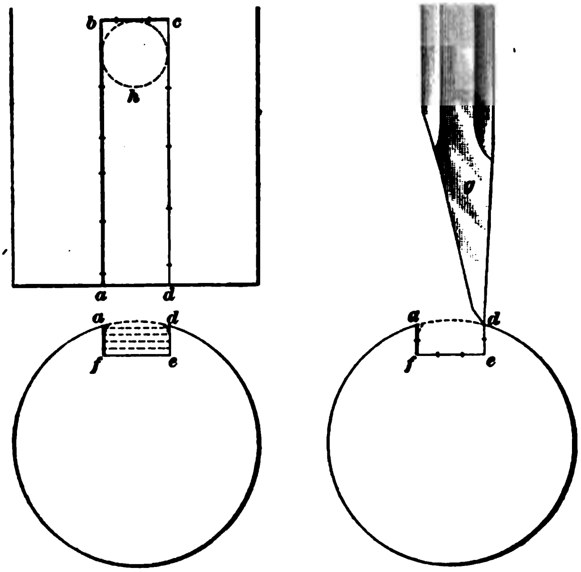


FIG. 39

the parts have been chipped to fit approximately, they are finally finished by filing.

52. Chipping Piston-Valve Bushing.—Fig. 39 is an illustration of a class of work which is frequently finished by chipping. In the figure *a* represents the bushing of a piston valve in which two series of ports *b* and *c* must be cut out of the solid metal. The ports are laid out in the usual way, the outline *d* being clearly marked on the surface. The bushing is then taken to the drilling machine and the ports are drilled out, just enough stock being left outside of the drill holes to insure a good finish. The holes may be drilled so close together that when the drilling is finished the block of metal may easily be removed by a blow with the hammer. The ridges between the drill holes are chipped away, as shown in the illustration, and the sides of the ports are finally finished to the lines by filing.



(a) FIG. 40 (b)

53. Chipping Keyways.—The keyway is first laid out as shown by the lines *a b*, *c d*, *e f*, Fig. 40 (*a*). The lines are sometimes marked with a prick punch, as shown. The side lines *a b* and *c d* of the keyway should be marked with a deep chisel cut, as shown at *a* and *d* in the end view, to prevent the material from tearing out along the sides of the keyway during the first cut with the chisel. This cut is best if made with a side chisel *g*, in (*b*), that is ground and held as shown in the figure. An ordinary flat chisel may be used for this work, if ground to a rather sharp angle and held so as to bring one of its cutting sides square with the side line *d*.

54. A cape chisel of proper width is used to remove the stock, several light cuts being driven through the keyway as indicated by the dotted lines in Fig. 40 (*a*). The keyway, if long or at the end of the shaft, may be finished by filing; but when it is in the middle of the shaft the finishing must be done with chisels.

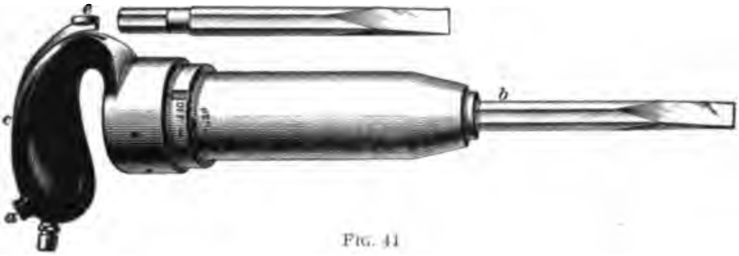


FIG. 41

When it is considered easier to drill out the stock before chipping, a line of holes like that marked *h* is laid out and drilled to the right depth, the bottoms squared with a square-end drill, and the remaining stock chipped to the lines. This method is especially applicable to large keyways.

55. Keyways in pulleys and gears are often chipped in. They are first laid out on both ends of the hub and lines drawn through the bore. If the keyway is a narrow one, a chisel of corresponding width is used, and the cut driven from each end; but if it is wide two or more narrow parallel grooves are chipped through and the stock between is removed with a flat chisel.

56. Pneumatic Chipping Hammer.—The pneumatic chipping hammer, illustrated in Fig. 41, is sometimes used for chipping, and has some advantages over the hand method. It is supplied with air at a pressure of about 80 pounds per square inch, through a small hose connected to the hammer at *a*. The operator holds the chisel *b*, which has a hexagonal shank fitting a similarly shaped socket in the device, in his left hand, as in ordinary chipping, and the device by the handle *c* in his right hand, with the thumb on the trigger *e*. Heavy or light blows may be struck, as the operator desires, by regulating the pressure of the thumb upon the trigger. The whole is held firmly in position against the work, and light pressure applied to the trigger to start the chisel into the metal. As soon as the cut is started, more air may be admitted to the tool, making it strike harder and faster. The blows struck by this hammer are so rapid that the chisel has almost a continuous cutting motion.

Pneumatic hammers of this type are used for many purposes; some of them have round instead of hexagonal bushings for holding the chisel. The chisels are not gripped in the device. For this reason the round-shanked chisel must be guided by the left hand. The chisel with the hexagonal shank is easily directed by the handle *c*.

FILING

57. Use of Files.—In finishing machine parts, there are many cases where a smaller reduction in size or a more perfect surface is required than can be obtained by the use of machine tools or by chipping. For both of these purposes great accuracy can be obtained by the careful and skilful use of files. In order to smooth a rough surface, files of various degrees of fineness are employed, a coarse one first, followed successively by finer grades, the piece being finished with the finest. A file is made of a piece of steel of the desired shape and size, and has a series of grooves cut across its face. When a file is passed over the surface of a body of metal or other material, the teeth formed by the grooves act on it as a series of small chisels or cutters, each removing a tiny chip. By passing the file across the surface successively, the high parts are removed. Each file, however, leaves its own marks, and these are removed, if desired, by means of the finer grades of files.

58. Chattering When Filing.—Files were first cut with regularly spaced teeth; but this method was found objectionable, because, in filing, the teeth follow each other at regular intervals and drop into the cuts made by the preceding ones, causing chattering. Hand-cut files are more satisfactory, as the slight irregularity in the spacing prevents chattering. This difficulty in machine-cut files was overcome by gradually increasing the spaces between the teeth from the end of the file to the middle, and again decreasing as the other end is approached. In this way, enough variation is produced to prevent the chattering, without causing enough change from the true spacing to affect the working conditions. By this method of cutting, called the *increment cut*, the two ends of the file are of the same coarseness, while the middle is somewhat coarser.

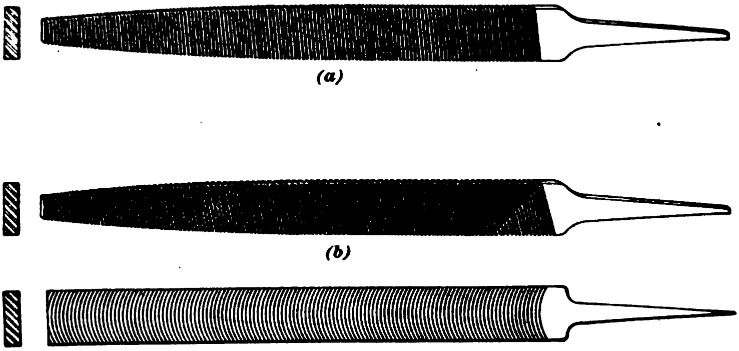
Files are also cut with the gradations of spacing running from end to end, the spacing being finer at the point and increasing gradually to the shoulder, thus accomplishing practically the same result as in the style just mentioned. This is also known as an increment cut.

59. Chattering is also prevented by cutting the teeth slightly out of parallel. By changing the direction of the deflection several times in the length of the file, enough variation may be obtained to avoid chattering. Files cut in this way are largely used at the present time. By varying the angle of the motion of the file gradually during the forward stroke, when there is a tendency to chatter, the regularly spaced file will work smoothly and well; hence, this style of file is still in use.

60. Forms of File Teeth.—The teeth of files are not generally cut at right angles to the sides of the file, but either at an angle or in a curve. The angle or curve varies for different materials. Most files used in machine shops are cut in one of three different ways, and are known as the *single-cut, double-cut* and *circular-cut files*. In Fig. 42 (*a*) is shown a single-cut, in (*b*) a double-cut, and in (*c*) a circular-cut file.

61. Single-cut files are cut with a single series of teeth running continuously from one end of the file to the other, as illustrated in Fig. 42 (*a*). They are used almost entirely for filing in lathes, and for filing the softer materials, such as lead, wood, horn, etc.

62. By making another cut, at an angle to the first, or over cut, a file is produced as shown in Fig. 42 (*b*), and is called a **double-cut file.** The second, or up cut, is generally cut a little finer and not as deeply as the over cut. The angles that the two cuts make with the axis of the file vary for different uses, the over cut ranging from 35° to 55°, and the up cut from 75° to 85°. The up cut has the effect of dividing the small cutting edges produced by the over cut into a large number of small pointed teeth. Files thus made in various grades of coarseness give excellent results.


(*a*)

(*b*)

(*c*)

FIG. 42

63. The shape and depth of the teeth of the **circular-cut file** resemble in section those of a milling cutter. The teeth of these files have an included angle of 60°, a front rake of 1½°, and a radius of 1¼ to 1½ inches. They are not increment-cut, as are the single- and double-cut files; consequently, when filing the angle at which the file is held to the work must be varied slightly throughout the stroke. A rather large chip is removed with light pressure, and the form of the tooth permits the chip to free itself. These files are used principally when considerable metal is to be removed, and also for lathe and finishing filing. On account of the large teeth used in this type of file, they are readily sharpened by grinding, as explained later.

64. Grading of Files.—Table I gives the classification of ordinary American files as to grading and their equivalent in circular-cut, English, and Swiss files.

The coarse and bastard cuts are used almost entirely on the coarser grades of work, and the second cut and smooth are employed in finishing and for the finer classes of work. The rough and dead smooth are rarely used in the machine shop, although occasionally a rough single-cut file may be required for work in lead or other soft material. The dead-smooth double-cut file is occasionally used on extremely fine work. The coarseness of the cut for each grade varies with the size of file, the cut being coarser on the larger files. Fig. 43 illustrates the comparative coarseness of 4-inch and 16-inch files, (*a*), (*b*), (*c*), and (*d*) showing the single-cut, rough, coarse, bastard, and second-cut files; (*e*), (*f*), (*g*), and (*h*) the double-cut, coarse, bastard, second-cut, and smooth files; and (*i*), (*j*), (*k*), and (*l*) the circular-cut, regular-fine, smooth, and dead-smooth files.

TABLE I

GRADING OF FILES

Ordinary American	Circular Cut	English	Swiss
Rough		Rough	
Coarse		Middle	
Bastard	Regular	Bastard	00
Second cut	Fine	Second cut	1
Smooth	Smooth	Smooth	2
Dead smooth	Dead smooth	Superfine	3

65. Sizes of Files.—The size of a file is generally indicated by giving the length in inches of the cut part, the tang not being included. Thus, a 10-inch bastard flat file means a bastard flat file 10 inches long from the point of the file to the tang.

66. Shapes of Files.—Files are divided into three general classes with regard to their cross-sections, as *quadrangular*, *circular*, and *triangular*. These classes of files are further sub-divided into *blunt*, *equaling*, *taper*, *hand*, and *safe-edge*, or *side*, *files*.

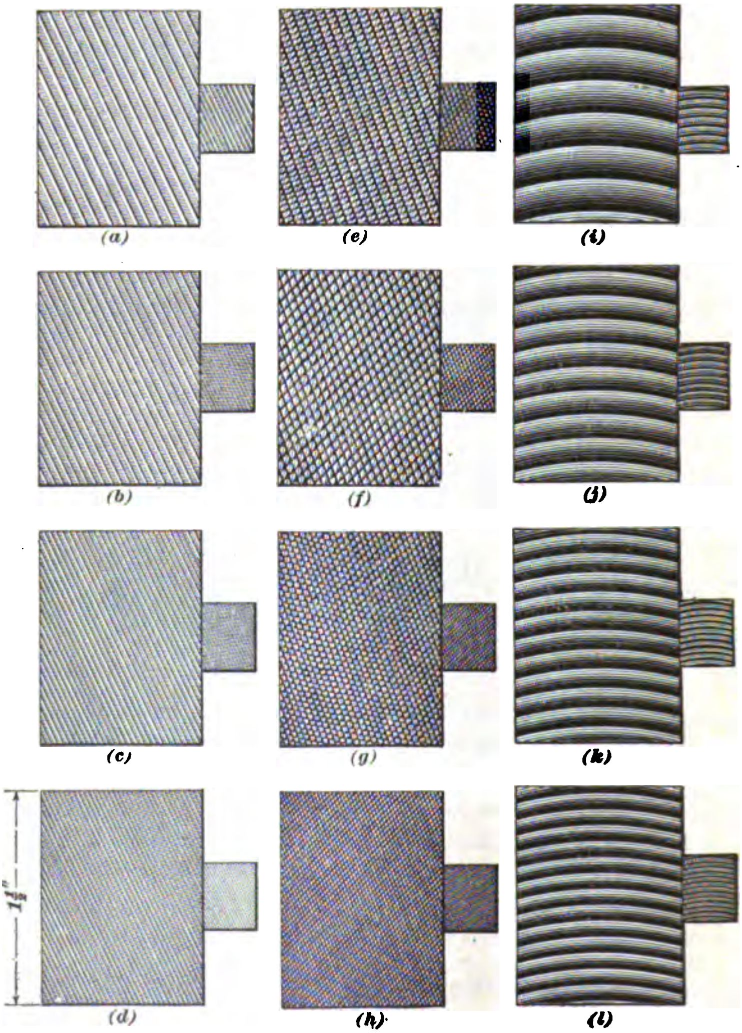
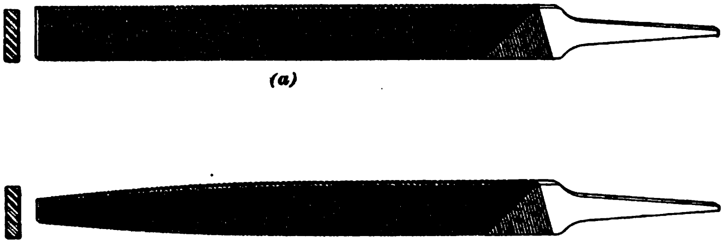


FIG. 43

67. A **blunt file,** Fig. 44 (*a*) has straight sides and the same width and thickness throughout. An **equaling file** is a blunt file whose edges have an exceedingly slight curvature, extending from point to the tang. A **taper file** is one whose sides are tapered, as shown in (*b*). The same name is also given to the three-cornered or triangular, hand-saw file. A **hand file** is one having its sides parallel and its thickness from point to tang tapering. A **safe-edge,** or **side, file,** has one or more of its edges or sides smooth or uncut, that it may not injure that portion of the work which does not need to be filed.

68. Table II gives the characteristics and uses of the files commonly used in the machine shop. The degree of coarseness of cut given is that of the ordinary American file. The equivalent in grade of other types of files can be found by referring to Table I.


(*a*)

(*b*)

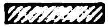
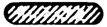
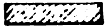
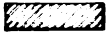
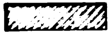
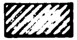
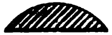
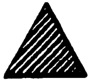
FIG. 44

69. Purpose of Filing.—In machine construction many parts must be finished by hand. The part may have been finished as far as possible in a machine tool, but the surface could not be made sufficiently smooth; or it may be so located, or of such a character, that a machine tool cannot be used, and the entire work must be done by hand. In the latter case, the excess of metal may be removed with a cold chisel, and the work then finished by filing.

70. The operation of filing is one of the most difficult of machine-shop operations, and the quality of the work produced depends almost entirely on the skill of the workman. In most

TABLE II

CHARACTERISTICS AND USES OF FILES

Comparative Cross-Sections of Files	Name of File	Common Lengths Inches	Character of Cut	Coarseness of Cut	Shape	Use
 	Mill Mill blunt Round-edge mill	4 to 16	Single	Mostly bastard	Taper Blunt One or two round edges	For lathe work, draw-filing, and to some extent for finishing brass and bronze
	Equaling	6 to 12	Double	Mostly bastard	Blunt	For general machine-shop work. (Seldom called for)
	Flat Flat blunt	4 to 16	Double Circular	Mostly bastard; many second cut and smooth; some dead smooth	Taper Blunt	Used by mechanics generally for a great variety of purposes—one of most common files in use
	Hand	4 to 16	Double Circular	Mostly bastard; many second cut and smooth; some dead smooth	Parallel sides and tapered thickness	Preferred by machinists for finishing flat surfaces. Its shape and its having one safe edge make it particularly useful where the flat file cannot be used
	Pillar	6 to 14	Double Circular	Mostly bastard; many second cut and smooth; some dead smooth	Parallel sides and tapered thickness	For general machine-shop use on narrow work
	Square	4 to 16	Double Circular	Bastard	Taper	Almost all branches of mechanical work; principally for enlarging holes of rectangular shape
	Square blunt	10 to 20	Double Circular	Bastard	Blunt	For the rougher work in finishing or enlarging mortises and keyways, when of considerable length
	Round Rat tail, or mouse tail Round blunt	4 to 16	Single (spiral)	Mostly bastard	Taper Blunt	For enlarging round holes and for shaping the fillets on the internal angles
	Half-round Half-round blunt	4 to 16	Double. Single on convex sides of grades finer than bastard Circular	Mostly bastard; many second cut and smooth; some dead smooth	Taper Blunt	Wide use in machine shops
	Three-cornered, or triangular	6 to 14	Double Circular	Mostly bastard	Taper	For filing acute internal angles, clearing out square corners, filing up taps, cutters, etc.

machine-shop operations, the tool is guided by the machine, as in a planer, shaper, or milling machine. In hand filing, the accuracy of the work depends on the motion of the hands, with no means of guiding the tool.

71. Convexity of Face.—A convex file surface will produce the best results. The pressure of the hands on the two ends of the file tends to spring the file and make the lower face concave; also, when files are being hardened, they have a tendency to spring, thus making it impossible to produce files that have perfectly straight surfaces.

In filing wide surfaces, a perfectly straight file would require a very heavy pressure to make it take a cut; while the same file on a narrow surface would cut under a very light pressure. In the latter case, the pressure is concentrated on a few teeth; while in the former it is distributed over a large number, and consequently to secure enough pressure on each tooth to make it cut, a very heavy pressure is necessary. A light pressure with a small number of teeth in contact will produce the best results. By making the files convex, only a few teeth will be in contact at one time, however wide the surface may be. The faces of files are, therefore, made convex for three reasons: to overcome the effect of spring due to the pressure of the hands, to overcome the spring caused by hardening, and to make the file cut on any width of surface.

72. Fitting Wooden Handles.—File handles are made of wood with a ferrule on the end, and having a hole to receive the tang of the file. As the sizes of the tangs vary for the different forms and sizes of files, the hole must be small enough to receive the smallest file for which it is intended. If the handle is made of a soft wood, the larger tangs may be driven in without splitting it; but when made of hard wood, the hole may be burned to about the right size by using the heated tang of a worn-out file of the same size as the one being fitted. If no old file is available, the tang of the new file may be heated. A piece of wet waste should be wrapped about the file up to the tang, to prevent its temper from being drawn. The handle should be driven well up to the heel of the file.

73. Special File Handles.—In filing broad surfaces, as the tops of lathe beds, and in finishing long slots, the ordinary wooden handle cannot be used. Fig. 45 shows a good form of handle. The end *a* is formed with a dovetailed slot that slips over the tang, while the point *b* rests upon the back of the file. The slot should be made to fit about the middle of the tang of a 12-inch file. The foot *a* should be about 1¾ inches long and the handle about ⅝ inch in diamter.

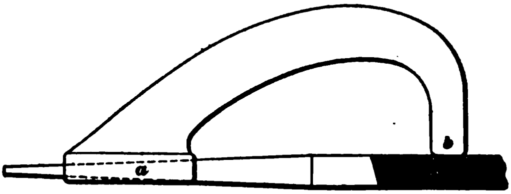


FIG. 45

74. Another handle that has some advantage over the one just described is shown in Fig. 46. A foot *a* rests upon the file and has a dovetailed slot that catches over the tang. A rod *b* has a lug *c* on its front end that catches over the point of the file. The handle *d* contains a nut that screws on the end of the rod *b*, and by means of which the file is held firmly between the catch *c* and the foot *a*. A column *e* at about the middle of the file makes the handle more rigid, and prevents the file from springing up in the middle when pressure is put upon it. A projection on the front end of the rod furnishes a convenient thumb rest.

75. Holding Files.—The right way to hold a file is learned as easily as a wrong one; but having once become accustomed to the wrong, it is very hard to change to the right. There is some difference of opinion as to the correct way, but the following is considered good practice:

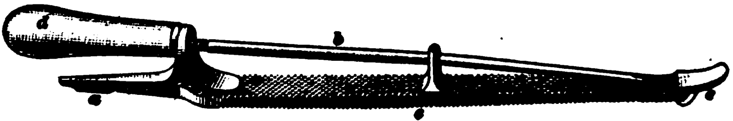


FIG. 46

In moving the file endwise across the work, commonly called *cross-filing*, it is generally held as shown in Fig. 47 (*a*) and (*b*); for lighter work, and in finishing cuts, the former illustration shows the relation of the hands to the file at the beginning of the stroke, and the latter at the end of the stroke. The point of the file is held between the thumb and the first finger, as shown in the two views, while the handle is held by resting the thumb upon it, as shown in these illustrations and in Fig. 48, and letting the end stand against the palm of the hand, the fingers gripping it lightly. When the work is heavy

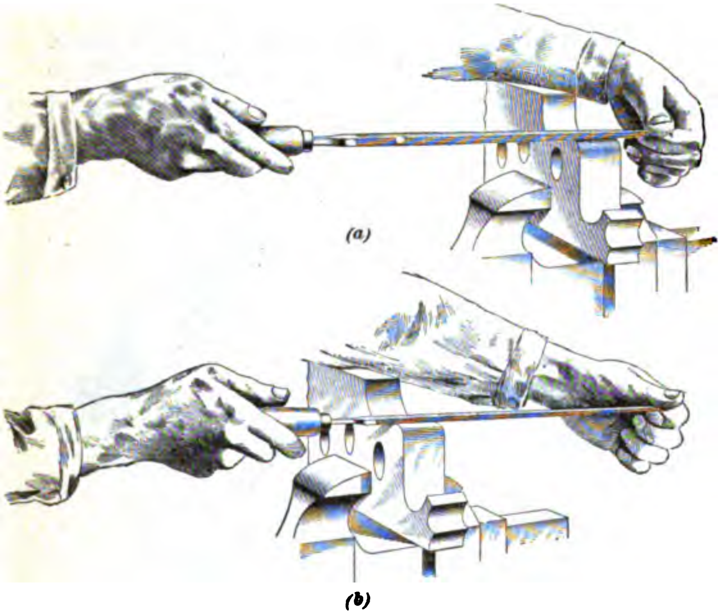


FIG. 47

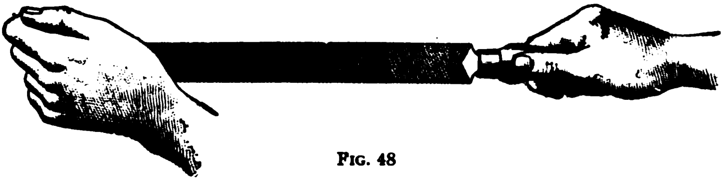


FIG. 48

and a large file is used, the ball of the left hand is placed on the point of the file, while the handle may be gripped as shown in Fig. 48. In the latter case the handle is gripped a little farther forwards than in the case of light work.

76. When the file is very thin, there is great danger of springing it so as to round the corners of the work. By holding it as shown in Fig. 49, a downward pressure is put upon both thumbs and an upward pressure upon the fingers of both hands.

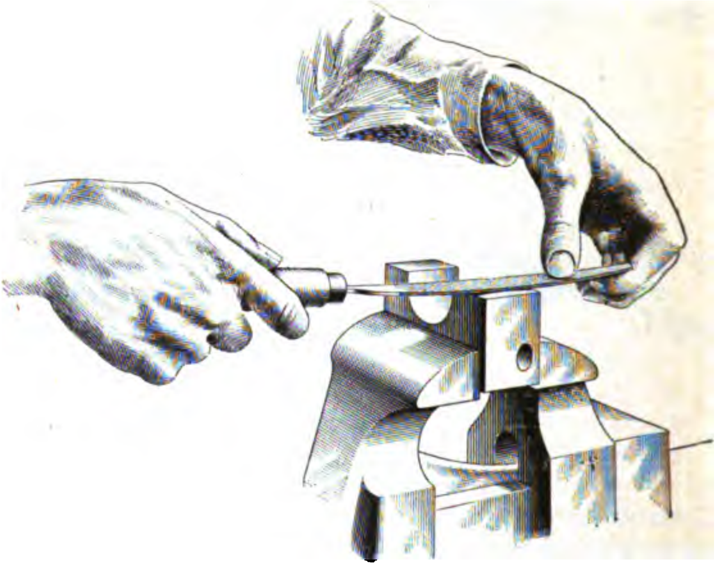


FIG. 49

This pressure is just sufficient to overcome the tendency of the ends to spring downwards. By making the pressure great enough to spring the file downwards considerably in the center, a concave surface may be formed in the work. It is very difficult, however, to hold a file in this way longer than a few minutes, and it is better to use a heavier file that has considerable convexity and stiffness, whenever that is possible. On very light files spherical handles are often used.

77. For internal work, when the hole is long, and it is impossible to hold the file at the point, a very great stress comes on the wrist of the right hand, which soon becomes tired. This stress may be relieved by placing the left hand over the right, as shown in Fig. 50. When the work is thin, so that the file will reach through the work far enough to take hold of the point, the ordinary method of holding it for outside work is generally used. In draw-filing, the file is grasped at each side of the work, as shown in Fig. 51.

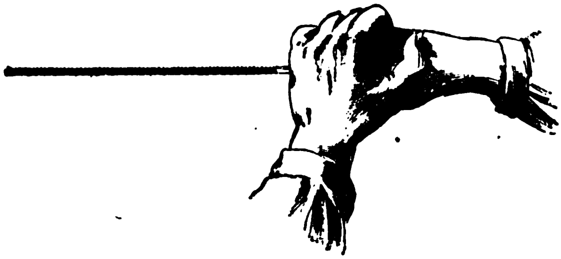


FIG. 50

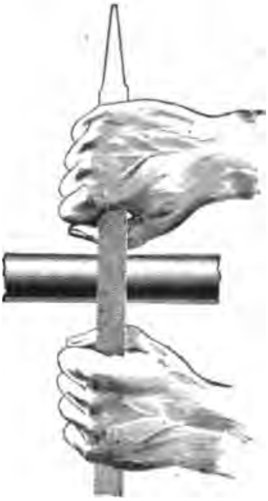


FIG. 51

78. Cross-Filing.—One of the most difficult, though most common, forms of filing is cross-filing. In moving the file back and forth, the hands tend to swing in arcs of circles about the joints of the arms, while the body sways more or less, depending on the work. To overcome these tendencies so as to move the file in straight lines requires a great deal of practice and careful observation of the results of certain movements. Filing on narrow work is especially difficult. The work becomes a fulcrum on which the file rests at different points along its course, and if an equal pressure is put on each end, it will tilt first one way, then another, depending on the point of contact and the leverage. For instance, in Fig. 52, when the file is in position *a*, there is a tendency for the handle to tilt downwards from the fulcrum *b*; when in the position *c*, represented by the dotted lines, the point tilts downwards about the fulcrum *d*. As the file runs forwards, there is therefore a tendency to file off the corners more than the middle of the piece and to produce a convex surface. On wide work this tendency is lessened. By persistent care to have the file rest evenly on the work, this difficulty may be entirely overcome.

79. **Filing Broad Surfaces.**—There is little danger of rounding the corners in filing broad surfaces, but other difficulties present themselves. Files for this class of work have convex faces, and only a few teeth cut at a time. The strokes must then be so gauged that an equal cut is carried across the entire piece. If numerous short strokes are made they are liable to overlap each other at some places and not meet at others, and to wear out the files at the middle while the ends are still good. Uniform strokes of as great a length as possible should be made.

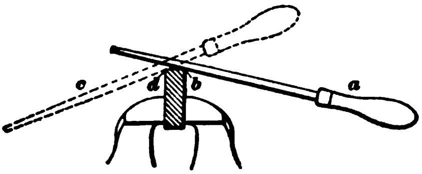


FIG. 52

When high spots are to be removed, the file must be so held that the teeth over these spots are in contact with the work. By commencing the stroke with the teeth near the point in contact, and lowering the handle gradually to compensate for the convexity, the effective work of the whole stroke may be concentrated on a small area. On the other hand, care must be taken that this is not done when the metal is to be removed evenly from a broad surface, or a concave or irregular surface will be the result. The file should move perfectly parallel to the work, or be gradually tilted so as to increase the length of the cut.

80. **Diagonal Filing.**—Small grooves are left on the work at each stroke in filing, and when the strokes are all made in the same direction these grooves become deeper; this increases the work to be done, because these marks must be removed by means of finer files. By changing the angle of the direction

of the stroke with the work, at short intervals, this difficulty may be avoided. The file will also cut more freely, as the grooves run at an angle to the cut and the particles are separated more easily. The workman can see where the file is cutting and gauge the stroke so that the desired part of the surface will be removed.

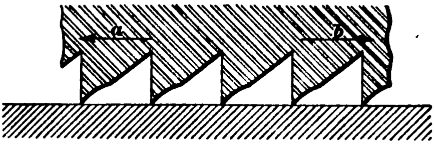


FIG. 53

Changing the course of the file as described above is often called *diagonal filing*. The angle that the strokes should make with each other depends on the work. Practice alone will enable one to determine what this angle should be.

81. Pressure on File.—In all kinds of filing there should be just enough pressure put on the file during the forward stroke to make it cut freely; but no pressure should be put on it during the return stroke. The teeth of a file are formed approximately as shown enlarged in Fig. 53. When pressure is put on the file and it is moved in the direction of the arrow *a*, the cutting edges are well supported and the angle of the cutting face and the clearance produce very good cutting conditions. When moving in the direction of the arrow *b*, which corresponds to the return stroke, these conditions are reversed. The angles are such that the teeth will simply drag over the work, without cutting, while the edges are poorly supported and any pressure put on the file will cause the teeth to break or wear away very rapidly without doing any work.

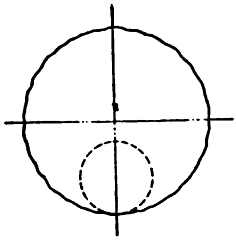


FIG. 54

82. Filing Curves.—In filing circular holes, a round file that is as nearly the size of the hole as it is possible to obtain should be used. A small file will tend to produce the ridges shown in Fig. 54; with a larger file that conforms more nearly to the curvature of the hole, this tendency is greatly reduced. When the filing is to be done on an internally curved surface of a large radius, as shown in Fig. 55, a half-round file is used. As in the case of the circular hole, there is a tendency to file unevenly, and a file of as large a curvature as is obtainable should be employed. The file should be moved along the circumference of the curve as well as across the work, which gives it a diagonal motion, and in addition to the advantages of diagonal filing on flat surfaces, prevents the formation of ridges.

83. Filing Into Corners.—When forming a sharp corner, or filing up to a finished surface that stands at right angles to the one on which the filing is done, a safe-edge file is used, thereby preventing any injury to the finished part. When the corner is to be extremely sharp, a half-round file may be employed, or a flat file may be ground off on one side to form a safe edge. Either the half-round or a flat file ground in this way has a sharp edge that will permit a sharp angle to be formed. Some forms of triangular files will also make a sharp corner. The other files used in ordinary work are so cut that the corners are either rough or slightly rounded and will not make a clean, sharp angle. When the corners are to be rounded, a round-edge file will give good results.

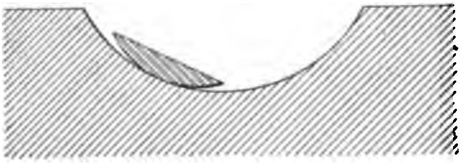


FIG. 55

84. Draw-Filing.—When the filing is done by moving the file sidewise over the work, it is called *draw-filing*. Fig. 51 illustrates how the file is held, the motion being at right angles to its length. Draw-filing is used very generally in finishing turned work, where it is desired to remove the circular tool marks and lay the marks endwise. The file must be held so that the teeth will cut as it moves away from the body and the pressure will be relieved on the return stroke, as in cross-filing.

Very smooth work may be done by draw-filing. The cut is not so deep as in cross-filing, the teeth standing at such an angle to the direction of motion that a light shearing rather than a cutting effect is produced. A second-cut or smooth file is best suited for draw-filing. On convex surfaces a flat file or the flat side of a half-round file may be used; but in concave work a round file or half-round file will give the best results. When a large amount of metal is to be removed it should be done by cross-filing, as the cut in draw-filing is so light that a very great amount of time would be required to remove it by this method.

85. Finishing Filed Work.—When a better finish is required than can be produced by draw-filing, the surface may be rubbed with fine or worn emery cloth and oil, the cloth being wrapped about a file or a piece of wood, which is used as in draw-filing.

86. Position of Body.—No attempt should be made to keep the body rigidly in one position while filing, especially on heavy work. A free, easy motion of the body, in the direction in which the file is moving, permits a greater force to be exerted without undue strain. In filing right-handed, the workman stands with his left foot toward the work, and as the file is moved forwards, a slight bending of the left knee will tend to throw the body against and upon the file, thus assisting in making the cut. During the return stroke the knee is again straightened as the body returns. A little practice will show the extent to which this motion of the body can be made to assist in the work.

87. Height of Work.—The height of the work largely depends on the class of filing to be done. Ordinarily, the surface to be filed should be about as high as the elbow of the workman. Extremely heavy work should be set somewhat lower, in order that a greater pressure may be put upon it. If the vise or supporting device is too high, a foot-board or low bench may be used to stand upon. The feet of the bench should be set flush with the ends of the foot-board in order to prevent tipping when stepping on the ends.

88. Effect of Oil.—The effect of oil on filing varies greatly with different metals and different classes of work. In finishing broad, smooth surfaces of cast iron, the presence of oil prevents the file from cutting, and causes it to slip over the surface, thus wearing off the sharp points of the teeth. On cast iron generally, and especially on the class of work mentioned above, oil should never be used. On the other hand, it may be advantageously employed when filing wrought iron and steel, and hard fibrous materials, especially in finishing surfaces, when the file is new and sharp. Oil prevents the file from scratching and cutting too deeply. Sometimes the teeth are filled with chalk, either dry or mixed with oil; this helps to prevent the filings from clogging between the teeth. New files are usually sent from the factory covered with oil, to prevent their rusting. For work in which oil is objectionable this must be removed, which is sometimes done by first rubbing off the surplus oil, then coating the file with chalk and brushing it off carefully.

89. Selection and Care of Files.—The life of a file may be prolonged by exercising care in selecting a suitable one for each piece of work, and in using it properly. A new file should never be used on rough cast iron from which the sand and scale have not been removed, nor on narrow surfaces. Both these conditions tend to break and dull the teeth. A worn file will do excellent service in both these cases. On narrow work, a worn file will give better results than a new one, the teeth on a new file being so sharp that the few teeth in contact will enter so deeply that they are liable to be injured and to scratch the work. A new file should be first used on brass or wide, smooth, cast-iron surfaces.

The files most commonly used in the machine shop are the 12-inch and 14-inch flat and half-round, double-cut bastard, and the 12-inch and 14-inch mill bastard. The other files mentioned are, of course, needed very frequently for finishing, or for special operations, and should be kept in stock.

90. Pinning of Files.—The tendency to pin is one of the most serious troubles to be met in filing. *Pinning* is the clogging of the cuttings in the file teeth, forming hard, sharp pins that scratch the work. It occurs more readily in some materials than in others. As soon as the slightest indication of pinning is observed, great care should be taken to keep the teeth cleaned. Sometimes this may be done by rapping the file against a wooden block or the work bench, or by rubbing the hand over it. A wire brush, called a *file card*, shown in Fig. 56, is used in most cases. Vigorous brushing in the direction of the teeth usually removes the pins, but in cases where the brush will not remove them, a piece of soft sheet brass, or copper or iron wire flattened out at one end, may be used. The end is pressed crosswise upon the teeth and moved in the direction of the length of the teeth. Little grooves will be cut in the soft metal, forming small teeth that clean the file thoroughly.

91. Care of Files.—In too many cases, tools of all kinds are thrown into a box or cupboard promiscuously, resulting in injury to the files and all other cutting edges, to say nothing of the slovenly appearance of the place and the time wasted in searching for anything that is wanted. A tool box or cupboard should always be kept in order. There should be "a place for everything and everything in its place," when not in use. Files should never be thrown upon one another, or upon other tools or hard substances. They should be laid either on shelves or in a drawer that is provided with small divisions, to prevent their rubbing against each other. They should always be carefully cleaned before they are put away, and kept in good condition so as to be ready for use when they are required.

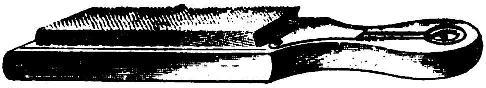


FIG. 56

92. Filing Jigs.—In the making of duplicate parts, filing jigs are generally used, and also in a great variety of operations where it is necessary to produce accurate work by filing, and to do this practically independent of the skill of the workman. Such jigs usually consist of hardened steel blocks fastened to the work, and made in suitable shapes to guide the file so as to remove the stock to the proper form in each case. The file will glide over the hardened jig practically uninjured and cut away the softer metal of the piece of work which projects above it.

93. The form of jig shown in Fig. 57 is used in making rectangular slots in boring bars, etc. It consists of a hardened steel block *a*, having a hole for inserting the work *b*; a slot *c* of the dimensions required to be made in the work; a series of holes *d* at right angles to the slot *c* and circumscribed by a rectangle same as *c*; and a setscrew *e* to hold the jig on the work.

94. In cutting such a slot in a bar, the jig is slipped on to the proper position and clamped by means of the setscrew. The holes are then drilled through the work, those in the jig serving to guide the drill. The setscrew is then loosened and the jig turned 90°, bringing the opening over the holes just drilled. A drift may be used to drive out some of the metal between the holes, after which a file is employed to bring the slot to the form of that in the jig.

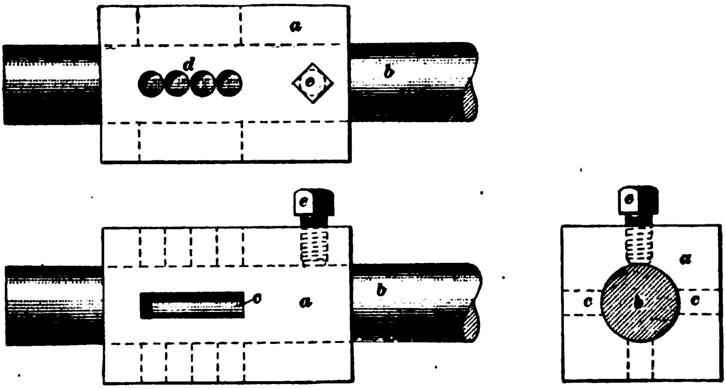


FIG. 57

A better way is to move the jig a half hole endwise, then, using the drill press, run a **butt mill**—that is, an end mill having end teeth only—through each hole of the jig to remove the metal left between the holes by the drill; the slot may then be finished by filing as described above.

95. Filing Machines.—Filing machines are used to file rough flat work on which heavy cuts may be taken; such as small castings of iron, brass or steel, forgings, stampings, etc. On them much work generally done on shapers, milling machines or disk grinders may be done more quickly.

One form of filing machine is shown in Fig. 58. The work *a* is held in an ordinary vise *b* attached to the table *c* of the machine, and is set square by the use of the straightedge *d*, which is adjustable about the standard *e*. The mechanism carrying the file *f* is so constructed that it may be moved in a horizontal plane about the pillar *g*, and is, of course, moved out of the way before adjusting the work in the vise.

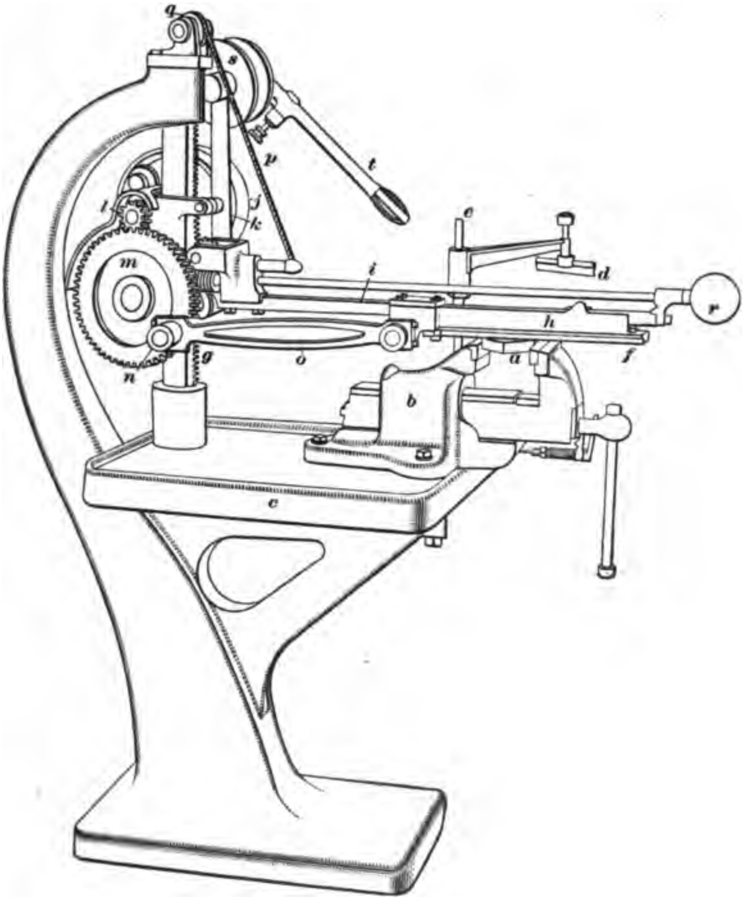


FIG. 58

The file has a flat face and is carried on the holder *h*, to which it is attached by means of screws. The holder has a reciprocating motion along the guide *i*. The machine is driven by a belt from overhead, operating on the tight and loose pulleys *j* and *k*. The pinion *l*, which is keyed to the same shaft as the tight pulley, drives the gear *m*. This gear, by means of the crankpin *n* and rod *o*, imparts the desired motion to the file holder *h*.

The weight of the guide bar, file holder, and other parts is counterbalanced by a weight in the base of the machine, which is attached to the cord *p*. This cord passes over the pulley *q* and through the stationary pillar *g*. By turning the wooden ball *r*, the counterbalanced body of the machine may be raised or lowered to set the file level or at an angle with the work. The flanged pulley *s* over which the belt runs serves to keep the belt taut, and, by adjusting the starting lever *t* sidewise, the flanged pulley shifts the belt. When filing, pressure is applied by the hand to the ball *r*.

96. Sharpening Machines for Circular-Cut Files. When files become dull, they are sometimes resharpened. Owing to the fine spacing and shallow depth of the file teeth, the sharpening of single- and double-cut files has met with little success. In circular-cut files, the teeth of which are widely spaced and relatively deep, the resharpening has proved advantageous.

A form of file-sharpening machine adapted to the resharpening of circular-cut files is shown in Fig. 59 (*a*). The base *a* of the machine carries a table *b* which has a crosswise movement controlled by a screw and knob *c*. On the table is a carriage *d* with wheels *e* that roll on the **V**'s *f* of the table. On the carriage the file *g* to be ground is held. It is placed against the stop-plate *h* and is held in position by the jaw plates *i*, which are moved crosswise by turning the knobs *j*.

The grinding wheel *k* is secured to the shaft *l*, to which the pulley *m* is keyed. The pulley is driven by belt from an overhead shaft. The shaft *l* has its bearing in the wheel bracket *n*, which can be moved back and forth on a horizontal slide *o* by means of the screw *p*. This slide is swiveled on the pin *q*, which is fixed in a vertical slide *r*. The wheel, wheel bracket, and swivel are swung about the swivel pin by the lever *s*, which is operated by hand. The vertical slide *r* is moved by the screw *t*, on the bracket *u*. The bracket is bolted to the base of the machine. A guide finger *v*, view (*b*), bears against the teeth of the file and locates them in position for grinding. It is held in the yoke *w*, which is secured to the rods *x*. These rods slide in the wheel bracket *n*, view (*a*), and have a vertical movement controlled by the screw and knob *y*. The grinding wheel *k* is thin, is well supported by flanges, and is covered by a guard *z* to prevent the pieces from flying if the wheel should break.

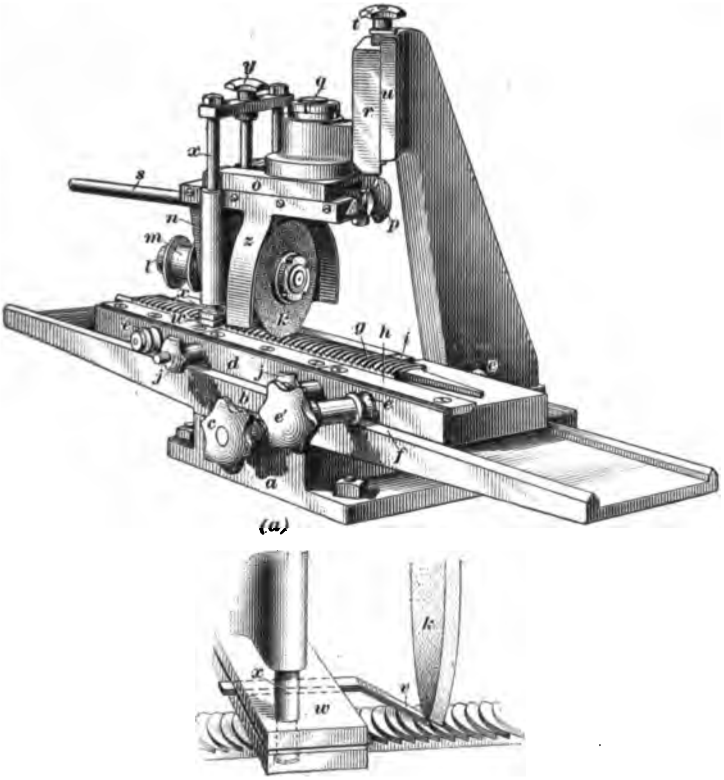


FIG. 59

97. In operation, the file is secured to the carriage of the machine, the wheel is trued to an angle a little less acute than that of the file tooth, the table is adjusted crosswise until the file is located centrally under the wheel, and the guide finger is set against the tooth of the file farthest to the right. By turning the knob *p*, Fig. 59 (*a*), the radius of the arc in which the wheel swivels is adjusted until it corresponds with the radius of the teeth of the file. The wheel is now adjusted vertically, by means of the knob *t*, to grind the first tooth. When grinding, the right hand is placed on the knob *e′*, and, by applying a slight pressure toward the left, the tooth to be ground is kept against the guide finger. The lever *s* is then operated by the left hand, and the grinding wheel is passed back and forth over the work. The wheel is now swung free of the file, the guide finger and carriage are set to grind the next tooth, and the operation is repeated. This process is continued until all the teeth are ground.

BENCH, VISE, AND FLOOR WORK

(PART 2)

BENCH AND FLOOR WORK

SCRAPING, BROACHING, AND KEY FITTING

SCRAPING

1. Use of Scrapers.—Scrapers are used in machine construction to fit or correct flat bearing surfaces to each other and to make flat or curved surfaces true. Flat surfaces are first planed, or in some cases milled, as true as possible; but owing to the unequal hardness or texture of the material, the possible springing of the work when clamped on the planer or milling-machine table, and the slight wear of the finishing tool, they are never perfect as they leave the machine. Such errors in planed surfaces as are corrected by scraping are caused in several ways, among which are: wind, from not having the casting or piece firmly bedded on the table; out of square, from using try squares that are not true; from angles that do not match; and from sand holes, spots of scale, and hard spots that the tool jumps or slides over. The errors in planed work should not exceed one or two thicknesses of tissue paper; if greater, the work should be replaned unless the errors are due to hard spots.

2. Forms of Scrapers.—The scrapers used on flat and angular work are the *flat*, the *hook*, the *right-hand hook*, and

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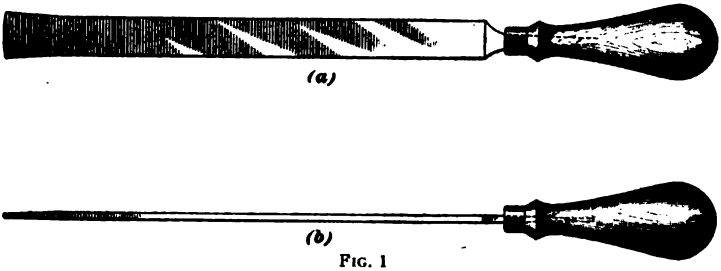
the *left-hand hook;* and for curved work, the *half-round* and *half-round end* are much used. For removing burrs and scraping corners and countersunk surfaces, the *three-cornered scraper* is generally used. The flat scraper is the one most employed, as it is the most easily made, sharpened, and used, and in expert hands it will remove an astonishing amount of surface in a short time with little effort.

Scrapers are often made of old files; but they do not work as well as those forged from special scraper steel, because files are made of a grade of steel, called *file steel,* that can be properly hardened only by special processes. Scrapers that are not shaped like files are never made from them. The half-round and three-cornered scrapers may be made from any good smooth or dead-smooth files that have become too dull to use, by simply grinding off the teeth, thus avoiding the necessity of rehardening. When scrapers are made in this way, care must be taken not to draw the temper of the steel when grinding.


(a)

(b)

FIG. 1

3. The **flat scraper,** Fig. 1 (*a*) and (*b*), should be made of special scraper steel stock about $\frac{3}{16}$ inch thick by 1 inch wide, with a tang, similar to that on a file, which is driven into a wooden handle. The cutting edge should be drawn to about $\frac{1}{16}$ inch thick by $1\frac{1}{4}$ to $1\frac{5}{8}$ inches wide, and hardened to the greatest possible degree.

4. The sides *a* and *b* of the scraper are ground a little high in the center as shown exaggerated in Fig. 2 (*a*), which is an end view of Fig. 1 (*b*). The end is slightly rounded, as shown in Fig. 1 (*a*). When grinding the end a small grinding wheel and the tool rest are used. The height of the tool rest is set so that when one of the broad sides of the scraper is laid on it, the plane midway between the sides will pass through the center line of the wheel. Keeping the broad side of the scraper flat on the tool rest, the end is ground rounding, as shown in Fig. 1 (*a*), and at the same time hollowed, as shown at *g*, Fig. 2 (*b*), which is an enlargement of the end of Fig. 1 (*b*). The surfaces *a* and *b*, Fig. 2 (*b*), are next rubbed on an oilstone, after which the tool is held in a vertical position so that both of the points *c* and *d* will rest on the stone, in which position it is rubbed back and forth, grinding it into the shape shown by the dotted line *e f*. It is now ready for use and has an equally good cutting edge on each side.

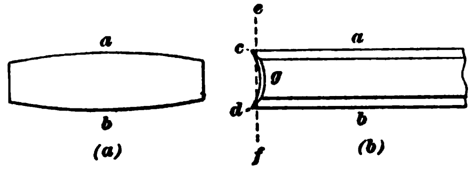


Fig. 2

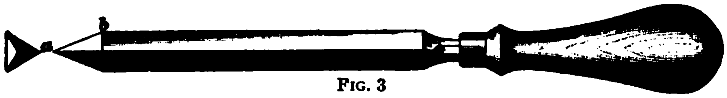


Fig. 3

5. The **three-cornered scraper** may be made of a worn-out file. All the teeth are ground off and the end is ground to an angle of about 60°. It is best to do the work on a wet grinding wheel, for, if a dry wheel is used, the tool would be easily

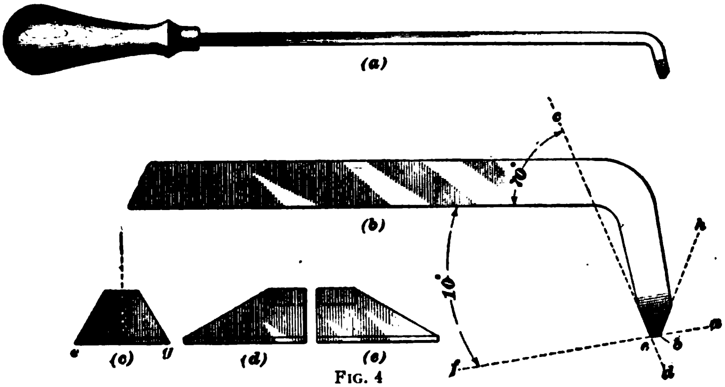


Fig. 4

overheated and spoiled. The appearance of the finished three-cornered scraper is shown in Fig. 3. In some cases the edges from *a* to *b* are slightly curved.

6. The **bent, or hook, scraper** is made in the form shown in Fig. 4 (*a*). An enlarged view of a portion of the tool is shown in (*b*), and an end view is illustrated in (*c*). This scraper should be ground to the angles denoted by the lines *a f* and *c d* in view (*b*). The cutting is done with the edge *e g*, in (*c*), and the metal is removed by pulling the tool toward the operator. The face *b h* in (*b*) is ground to any convenient angle, reducing the thickness of the clearance face *e b* to from $\frac{1}{32}$ to $\frac{1}{16}$ inch. As with all scrapers, the final sharpening of the cutting edge is done by rubbing it on an oilstone. This scraper is used for frosting or flowering; that is, the finishing of the surface in imitation of frost or designs. This tool is sometimes made with the end bent at right angles to the body of the scraper instead of as shown.

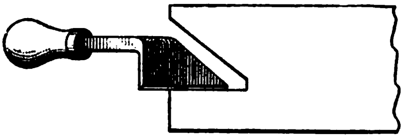


FIG. 5

7. Right- and left-hand hook scrapers are also shown in Fig. 4. The top view of these scrapers is shown in (*b*), the end view of the left-hand scraper in (*d*), and the end view of the right-hand scraper in (*e*). Scrapers of this form are employed to scrape surfaces that cannot be conveniently reached by the regular hook scrapers. They are used for both scraping and frosting, like the regular hook scrapers, by pulling the cutting edge toward the operator. In Fig. 5, a left-hand hook scraper is shown in position to scrape the lower side of a gib way. These tools are made with their ends bent at right angles to the body of the scraper more frequently than are the regular hook scrapers.

8. Scrapers for curved work are shown in Fig. 6. Fig. 6 (*a*) illustrates a form used for scraping bearings and similar work. It is made of scraper steel and fitted to a file handle. The scraping is done by pulling the scraper toward the operator.

The scraper shown in Fig. 6 (*b*) is made of a half-round file by grinding off the teeth, heating and bending to the desired shape, and hardening the file. If heating to a bright red and quenching in water does not harden it, case hardening is necessary. The scraping edges *a* of the tool are finished by oilstoning. This tool is largely used for scraping bearings. When made straight, as is sometimes the case, it is not heated, and care is taken not to draw the temper of the steel when the file teeth are ground off.

In Fig. 6 (*c*) is shown a form of *half-roumd end scraper* which is much used for scraping half-round channels such as oil grooves. It may be made from a worn-out, half-round file, although better results will be obtained when it is made of regular scraper steel. The scraping edge is that marked *b* in the figure.

9. Holding Scraper.—The manner of holding the flat scraper is shown in Fig. 7. The handle is held in the right hand with the thumb extended along the top, in order to keep the hand and arm in line, the same as in filing, thus preventing cramping the hand and tiring the arm. The left hand grasps the scraper as near the cutting edge as is convenient, and only enough pressure is applied to remove the required amount of metal. The cutting is done by pushing the scraper away from the operator, except where it is used for frosting, flowering, or finishing, when a long handle may be substituted and rested on the shoulder, while both hands are used to pull the tool toward the operator. The hook scrapers are held in much the same way as the flat scrapers, but are pulled toward the workman.

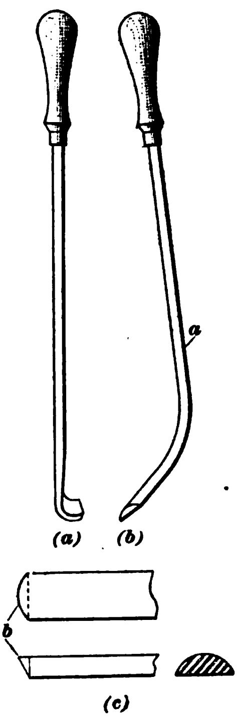


Fig. 6

10. The flat scraper is usually held at an angle of about 30° to the surface of the work; but this angle may vary with the material scraped and the condition of the cutting edges. No definite angle can be given for other types of scrapers; it must be determined by trial with each scraper and each class of work.

11. Preparation of Surface.—When a newly planed surface is to be finished by scraping, the piece is first placed on any support that will bring it up to a convenient height for the workman, and any dust or dirt that may be on the surface is brushed off. A smooth or dead-smooth file is run over the surface, to remove any burrs or fuzz; and any marks that would indicate that a sand hole or hard spot had left a high spot or spots, are removed by filing.

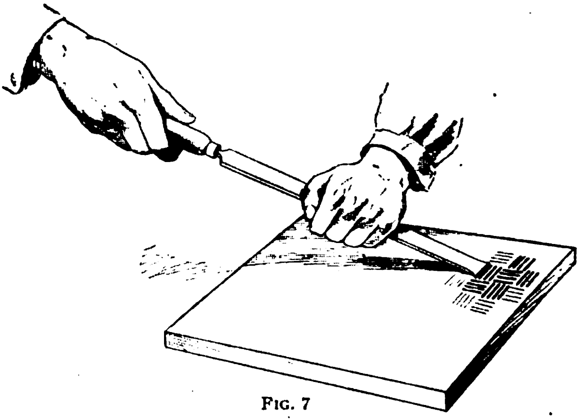
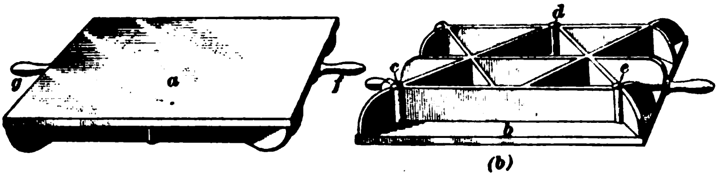


FIG. 7

12. Marking Mixtures.—To assist the workman to locate the high spots of the surface being scraped, marking mixtures are used. These mixtures may consist of red lead, Venetian red, or any red or black material that is not gritty. Venetian red is better than red lead, as it is much finer in texture. The marking is rubbed with the hand into a thin coating as evenly as possible over the surface plate on which the work is tried. The marking mixture should be kept in a covered tin box, so that it may be kept clean and free from grit.

13. Surface Plates.—In machine construction, the surface plate is used for testing flat surfaces. It is generally made of a hard, close-grained iron casting having a flat top *a*, Fig. 8 (*a*), supported by a ribbed back *b*, Fig. 8 (*b*). Three legs *c*, *d*, and *e*, are provided, so that the plate will stand evenly on any surface. On the ends are handles *f* and *g*, (*a*), by which the plate may be lifted. The tops of these plates are first planed as smooth as possible, then filed and scraped perfectly flat.

14. When in use, the surface plate is coated lightly with marking material, after which the plate is rubbed over the surface that is to be trued. The marking material is left on the high places, thus showing the parts that are to be removed with the scraper. This operation is repeated until the surface shows a good bearing at all points. Small work is rubbed on the plate. Every part of the surface plate should be used as evenly as possible, for if the rubbing is all done in one place, the plate will soon be spoiled. Surface plates are made of different sizes to suit the work. Special plates are often made for work, in places where it is impossible to use a plate having a ribbed back.



(*a*) FIG. 8 (*b*)

15. **Applying Surface Plate.**—The surface plate is prepared by thoroughly cleaning and coating it with marking material. It is placed face down on the work and rubbed back and forth a few times over the entire surface. No pressure is necessary, the weight of the plate being sufficient. When the plate is removed, irregular patches of the marking material will be found on the work. These places indicate high spots in the surface, and they are removed with a few strokes of the scraper. The workman now wipes his hand clean of grit and rubs it over the entire face of the surface plate, to smooth the marking, and then rubs the plate over the work again. More bearing spots will be shown this time, which are removed with

the scraper. The work proceeds in this manner until the entire surface of the work is covered with bearing marks, when it may be called true.

16. The marking material, in addition to showing the high spots on the work, acts as a lubricant and prevents undue wear on the plate and the cutting or scoring of both the work and plate. The more true the surface operated on becomes, the thinner should be the coating of marking on the plate. For some purposes the marking does not afford sufficient lubrication, and additional oil would prove detrimental to the work. In such cases a plentiful supply of turpentine should be used on the surfaces while they are being rubbed together. In addition to lubricating the surface, turpentine also facilitates the work of scraping.

HAND BROACHING

17. **Broaching,** or **drifting,** is the process of forming holes by forcing a cutter of the exact form required through holes previously drilled. In all broaching operations, the greatest amount of stock possible must be removed by drilling, and if much remains the broaching tools should be so designed that each tool will take out an equal amount of material.

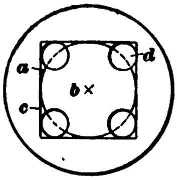


FIG. 9

For cutting most metals, broaches require an abundant supply of lard oil. When broaching cast iron, oil is not so essential for the cutting operation; but the back and sides of the broach should be well lubricated.

18. **Simple Square Broach.**—The form of broach depends largely on the nature and quantity of the work to be done. If the number of pieces to be broached is small, the broach must be as inexpensive as possible. In this case, most of the work is done by the drills, or other means are used to rough out the hole, and the broach depended on only for finishing.

Making a socket to fit a $\frac{1}{2}$-inch square in a tap socket or a chuck-screw wrench is a simple example of broaching. The square may be laid out on the end of the round stock, as in

Fig. 9. A ½-inch circle *a* is first drawn from the center mark *b*, and the square *c* is laid off. Four ⅛-inch holes *d* are now drilled ⅛ inch deeper than the square hole is to be and just touching the lines of the square. The ½-inch hole is next drilled, which leaves the hole as shown in Fig. 10 (*a*). A square broach may now be driven to the bottom of the hole. Fig. 10 (*b*) shows this form of broach; it tapers a little from the cutting edge *e* to *f*.

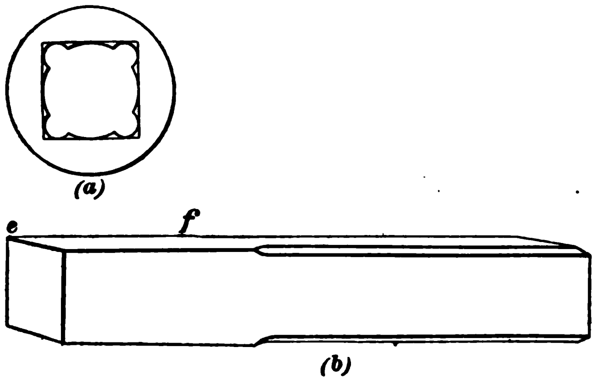


FIG. 10

19. Another Form of Square Broach.—Fig. 11 shows a broach and a broached piece. The broach in this case has rounded corners, which illustrates a practice that should be followed wherever practicable, as teeth of this form are much less liable to break than those of square-cornered broaches. The notches *a* allow the broach to be started without taking the whole cut, and when it has entered far enough to have sufficient support to steady it, the whole teeth *b* commence cutting and finish the work.

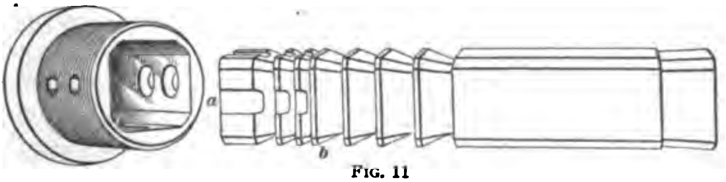
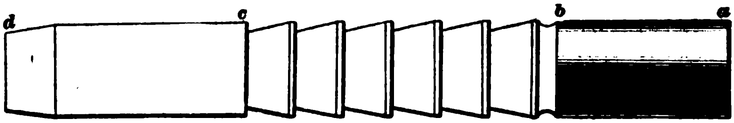


FIG. 11

20. Use of Several Broaches in a Set.—When a considerable amount of any given class of work is to be done, it is best to use several broaches following one another, each removing a portion of the stock. In the case illustrated in Figs. 9 and 10, the greater part of the metal at the corners is removed by drilling small holes, and in some cases additional metal is chipped out. Where much of this work is to be done, all the metal in the corners may be removed by passing a series of broaches through the work. In Fig. 12, the forms of four broaches for squaring a ½-inch round hole that extends through the piece are shown at *e*, *f*, *g*, and *h*. All the broaches should be provided with several cutting edges, as shown between *b* and *c*, and a guide pin, as shown at *a b*, Fig. 11.



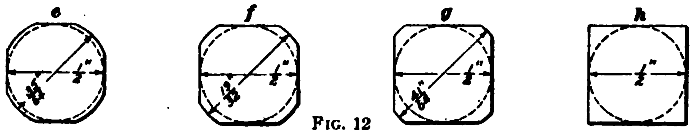


FIG. 12

21. Broaching Keyways.—Keyways can be cut to best advantage by the use of special machines for the purpose; but may be finished by hand broaching more quickly and accurately than by chipping. Sometimes, quite large and long keyways are formed in this way, the broaches being driven by means of sledges.

The necessary tools for broaching a tapered keyway are shown in Fig. 13. A plug (*a*) is turned to the diameter *c d* so that it fits the bore of the hub in which the keyway is to be cut. It is made of sufficient length to pass entirely through the hub, and is provided with a collar *e*, which rests against the hub when in use. A slot or keyway having the same taper as that required in the hub is cut in the plug, as indicated by the dotted line *a b*.

22. The cutting is done by the tool shown in Fig. 13 (*c*). The cutting edge is at *j*, and the thickness *g j* must be equal to the depth of the narrow end of the slot *b d*, view (*a*). In order to make the broach cut, liners are placed in the groove behind the broach; one of these liners is shown in (*b*). They are made of sheet metal, and, if the keyway is a large one, after several thin liners are in place they may be removed and replaced by one thick one, after which the thin liners may be replaced one by one, as the successive cuts are taken.

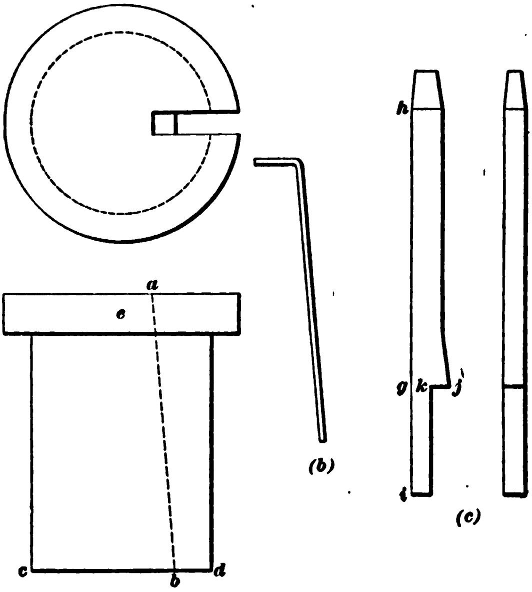


FIG. 13

The broach is provided with a guide *g i*, view (*c*), which enters the hole first, and the portion *g h* must be at least equal in length to the slot *a b*, view (*a*), so that the broach can be driven clear through. The face *j k*, view (*c*), of the broach should be perpendicular to the face to be cut. The broach, if very large, may be made of machine steel and provided with an inserted blade or cutter at *j*. The cutting edge of a broach should be hardened to a brown or dark straw color.

FITTING KEYS

23. **Rectangular Keys.**—Keys of a square or rectangular cross-section are generally planed or milled a little larger than the size of the key seats they are to fill, and are then filed to fit. If the key is to fit the top and bottom, it should be filed true to a surface plate and made of such width as to fill sidewise the keyways in both the shaft and wheel. The corners, as well as the ends, should be slightly rounded. The shaft is now put into the bore, with the keyways in line. Red or black marking should be put on the surfaces of the keyway, and the key driven in lightly and taken out and filed where it shows bearing marks. The key should not be driven too tightly at first, as it is easily sprung to conform to the inequalities of the hole, and will show too great a bearing. Neither should it be driven in dry, as it will surely cut. The marking applied to the seat is sufficient at first, and later the marking material may be put on the key, where it serves the double purpose of marker and lubricant. By repeated trials, the key is brought to fit the seat perfectly, and then may be driven home without danger of throwing the work out of true.

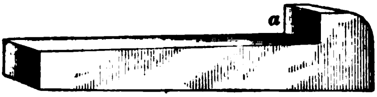


FIG. 14

24. A well-fitted hub and shaft may be forced considerably out of true by driving a key that is tight only on one end; and poorly fitted wheels and shafts may be made to run reasonably true by carefully fitting the keys and trying the work on lathe centers as it progresses. If means are not at hand for machining keys, as is often the case on repair work, a wooden pattern is first made and the key forged a little large, after which the scale may be ground off on an emery wheel or grindstone and the key filed to fit.

25. **Provision for Withdrawing Keys.**—When keys can be driven out by putting a set in the opposite end of the keyway, they are not provided with heads; but if the keyway is so located that only one end is accessible, that end must be

provided with a head, as shown at *a*, Fig. 14, for the purpose of withdrawing the keys. A pinch bar, or wedge, is used between the head *a* and the hub, to back this key out.

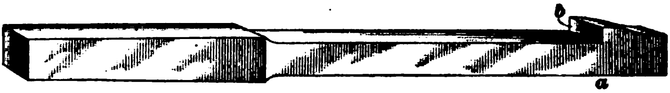


FIG. 15

26. For convenience in fitting, large keys are sometimes made with an extension head 3 or 4 feet long, as shown in Fig. 15. While backing out such a key, it should be supported by holding a sledge under the head at the point *a*, while blows are being struck against the face *b*.

27. Taper of Keys.—When keys are made with a taper, the taper is generally given on the drawing; but in some shops the workman is left to determine this for himself; in common practice, $\frac{1}{16}$ inch to $\frac{1}{8}$ inch per foot is found sufficient.

28. Round Keys.—Sometimes a cylindrical or tapered pin is used as a key. In this case a hole is drilled one-half in the shaft and one-half in the hub; and if the key is to be tapered, the hole is reamed to the proper taper. A tapered key is then turned to fit the hole, and fitted by filing in the lathe, after which it is driven home. For very small work where there is not much strain on the parts, this style of key may do very well. It is used very generally to fasten the hand wheels of globe valves to the stems. For large work, and especially where there is not a good fit between the hub and the shaft, such a key should never be used, as it has a tendency to burst the hub.

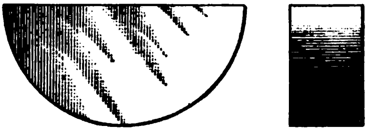


FIG. 16

29. Woodruff Keys. The keys of the form shown in Fig. 16 are known as Woodruff keys, and are made by cutting a disk from a piece of cold-rolled stock. The key seat in the shaft is made by sinking a milling cutter of a diameter corresponding to the curve on the key into the shaft to such a depth that the proper amount of the key will be left out of the shaft. The key is driven into the shaft, and the wheel, which has previously had a keyway cut in it whose depth is one-half its width, is driven lightly on the shaft. If the work has been correctly done, the key has only to be filed slightly to let the wheel into its place. This key bears sidewise, and should just fill the top and bottom. It is a short key, and when a greater length is required two or more are put in line.

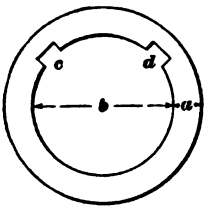


Fig. 17

30. Gauges for Laying Out Keyways. Different types of gauges have been adopted for laying out keyways on shafts and in bores having more than one keyway. For general work, the form shown in Fig. 17 will be found very useful. This gauge consists of a ring of cast iron *a* that is bored to the correct diameter *b*, and that has the necessary keyways laid out in it, as shown at *c* and *d*. This ring may be slipped over the shaft, and the keyways marked from it; it may then be removed and placed on a hub of the crank or wheel, and the keyways on it also marked out, thus insuring the accurate location of these keyways. After locating the keyways with the gauge, they are readily laid out on the shaft or in the bore, using a keyseat rule.

DRILLING, REAMING, AND THREAD CUTTING

DRILLING

31. Portable Drills.—The large amount of hand drilling required on medium and large work has created a demand for portable drills. Their light weight and compactness have made some of them available for much work that was formerly done by hand, and much time and hard labor may be saved by their use. Most of these machines are so light that they can be carried about and operated by one man. For erecting work, where electricity and compressed air are not available, the hand-power portable drills must be used. The several classes of portable drills are the *pneumatic*, *electric*, *flexible-shaft*, *ratchet*, *crank-driven*, *Scotch*, and *breast drills*.

32. Portable **pneumatic drills** are made in a large number of different forms. Some are driven by means of oscillating cylinders and others by vanes that act through gearing to give the proper reduction of speed. Fig. 18 shows one of the oscillating-cylinder type set up for drilling. The cylinders and gearing are enclosed in a housing *a*. The air, which for this class of work is generally compressed to from 80 to 100 pounds per square inch, is brought from the air compressor or storage reservoir to the drill through a rubber hose *b*, the hose usually being protected by wire wound spirally about it. The drill is fed by a screw *c* and is operated as indicated in the illustration. The air is turned on or off and the flow regulated by the throttle valve *d*, controlled by the hand of the operator. This type of machine will drill and ream holes up to 3 inches in diameter, and may be used for various other operations, such as tapping, grinding steam joints, etc.

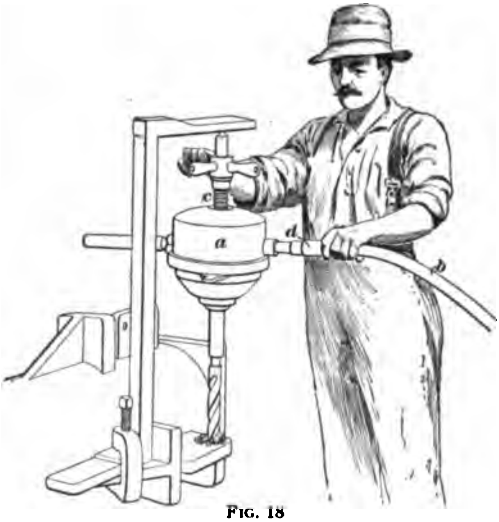


FIG. 18

33. Electric drills have the same general features as the pneumatic drilling machines, the difference being that an electric motor is substituted for the air motor. An electric drill is shown in Fig. 19. The motor by which the drill *a* is driven is inside the casing *b*, the wires *c* that supply current to the motor being led through one of the handles *d*. The drill is set and held and the feed is obtained in the same way as the drill shown in Fig. 18. If desired, the feed-screw *e* may be removed and the curved plate *f* may be attached instead, to enable the drill to be used as a breast drill.

34. A portable **flexible-shaft drill** is shown in Fig. 20. The power is transmitted to the flexible shaft *a* through a rope drive, the rope running from the pulley *b* on the driving end of the shaft, over a pair of idlers *c* hung from the ceiling, to a pair of idlers *d* attached to the floor, as shown, and thence to the pulley *e* on the countershaft. By either lengthening or shortening the rope attaching the idlers *d* to the floor, the pulley *b* may be moved to any location within the reach of the driving rope. A variable speed is obtained by means of the stepped pulley *e*. The flexible shaft is made by winding successive layers of wire in opposite directions about a center wire, as shown in Fig. 21, the outside being covered with leather.

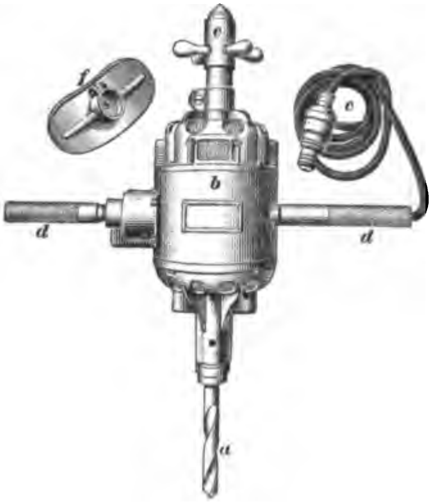


FIG. 19

35. The flexible-shaft drill illustrated in Fig. 20 is shown to a larger scale in Fig. 22. It consists of a pair of bevel gears *a* and *b* mounted in a frame *c*, a spindle *d*, a feed-screw *e*, and a hand wheel *f*. The bevel pinion *a*, which is covered by a guard, is attached to the flexible shaft, and the bevel wheel *b* is splined on the spindle *d*. The drill is held in the spindle in the usual

way, and may be set so as to drill holes at any angle. When no power shaft is available, the flexible shaft may receive its power from any convenient portable source, as, for example, a small electric motor mounted on a truck. The shaft is connected to the motor by a universal joint, so that the arrangement may be as flexible as possible.

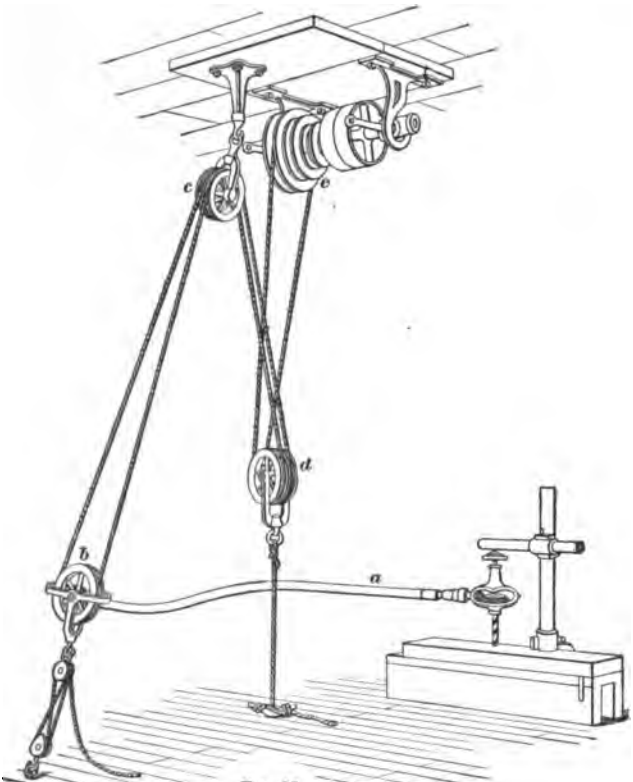


FIG. 20

36. The slowest method of drilling is by means of the **ratchet drill**, but there are occasions when no other kind of drill can be used. Ratchets are generally made single acting; that is, the drill only cuts during the forward stroke of the

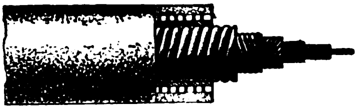


FIG. 21

handle; but some of the improved ratchets are made to give a forward rotary motion to the drill or cutter during both strokes. Ratchets are made to use both *square-* and *taper-shank* drills. The taper-shank twist drill is the better tool, but odd sizes are often needed by men out on repair work, where it is impossible to get the proper size of twist drill, and a square-shank flat drill can be made by any blacksmith or by the man himself; or a flat drill already on hand may be made into the required size in a few minutes, either by grinding or dressing.

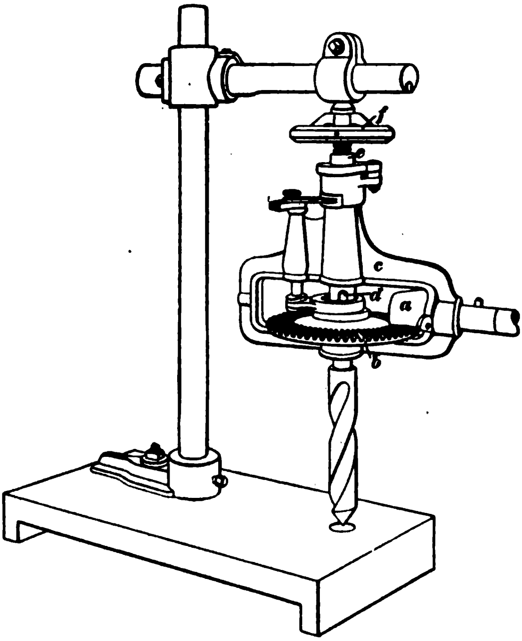


FIG. 22

37. The hole to be drilled with the ratchet is laid out and center-punched in the usual way. Some sort of brace, or, as it is commonly called in the shop, an *old man*, or a *drilling crow*, must be provided that will support the ratchet and drill in the correct position and at the same time allow the drill to be forced into the work by the feed-screw.

The brace, drilling crow, or old man, is made in a great variety of ways, from a piece of flat iron or steel bent to the proper form to the well-designed adjustable one shown in Fig. 23. This brace consists of a base *a*, an upright *b*, and an adjustable arm *c* that is held by the binding screw *d*.

The base is made fast to the work *e* by means of a bolt *f* or clamp *j*, as shown. The arm *c*, which has a number of center holes in its lower face, is set to such a height that the ratchet *i* and drill *g* will go under it. The drill is either set square with the work, or so that the ratchet end will lean slightly away from the upright, as the pressure upwards on the arm *c* will spring the upright *b* back and so draw the drill about perpendicular. The drill is rotated by means of the handle *h* and is fed into the work by means of the sleeve *R*.

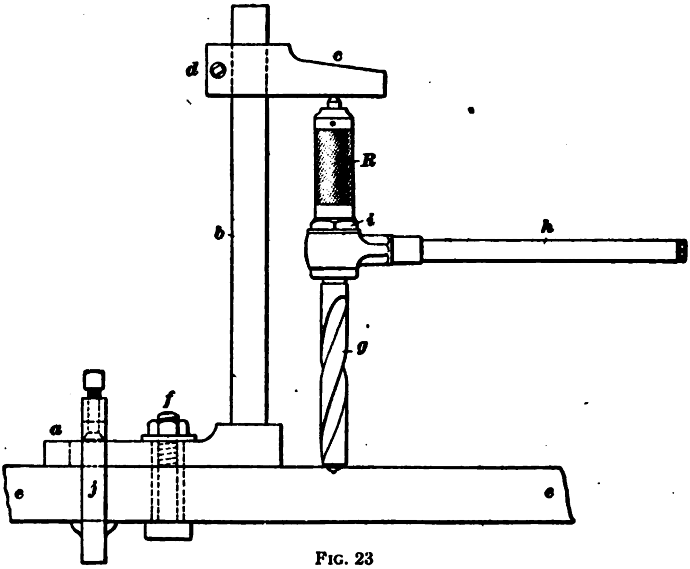


FIG. 23

38. The **crank-driven portable drill** is a better tool than the ratchet, where there is room to use it. This form of drilling machine is clamped to the work, or bench *a*, Fig. 24, and is operated by a crank *b* that gives a continuous motion to the drill *c*. The feed is operated by turning the hand wheel *d* with one hand, and the crank is turned by the other. The sleeve *e*, carrying the bracket *f*, may be adjusted to varying heights and positions on the upright *g*, being clamped in position by the screw *h*. The bracket *f* may be set to drill vertically or at any angle by adjusting the part *i* on its bearing, and clamping it in position by the handle *j*.

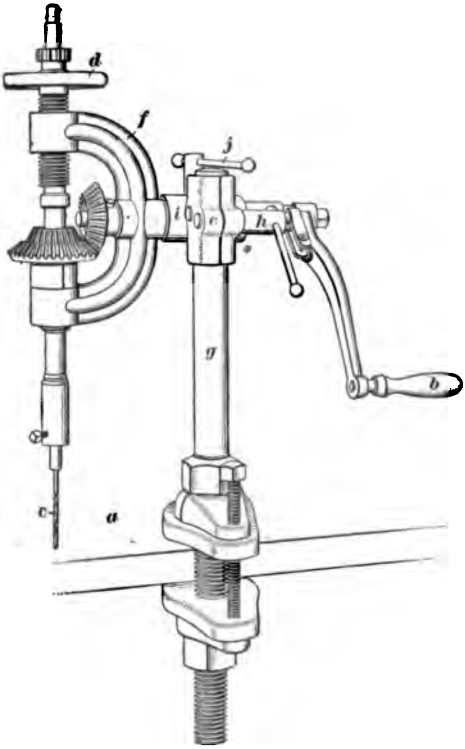


FIG. 24

39. The **Scotch drill** is a drilling device formed very much like an ordinary carpenter's brace. It is usually made by bending a piece of steel or iron so that it will form the necessary crank, fitting one end of it with a suitable socket for the drill, which may be either square- or taper-shanked. The other end is provided with a pointed center that may be fed out by means of a screw, thus giving the feed to the drill. The crank is rotated like an ordinary carpenter's brace, the drill being held in place by a knee or other suitable clamping device. Sometimes the Scotch drill is made with a double crank so that both hands may be used at the same time; but usually only one hand is employed, as the other is required to operate the feed-nut.

40. The **breast drill** is so named because it is provided with a suitable guard that may be placed against the breast while drilling, the feed being obtained by a pressure brought to bear on the drill by the body. The drill is usually operated through bevel gears by a crank on the side of the machine. This style of drill is very largely used for drilling small holes for attaching name plates, and for similar light work.

REAMING

41. Object of Hand Reaming.—The continued use of machine reamers dulls their cutting edges and at the same time slightly reduces their diameters. For some work, a hole $\frac{3}{1000}$ inch under size, such as would be produced by a worn reamer, would not be objectionable; but, in addition to being small, the hole will be comparatively rough. These defects may be overcome by hand-reaming the hole.

42. Ordinary Hand Reamer.—The hand reamer shown in Fig. 25 illustrates one form of this class of tools. The body *a* is finished to the correct standard size, and the shank is made of such size that it will act as a guide when the hole to be reamed is longer than the fluted part. The diameter of the part *b c*, equal in length to one diameter of the reamer, is made $\frac{3}{1000}$ inch smaller than the nominal diameter. From *c* to *d*, about one diameter, the reamer is tapered up to the full size, and from *d* up it is parallel. The hand reamer is used, as its name implies, only by hand. The end *e* is entered into the hole left small by the under-sized machine reamer and acts as a guide, and the taper from *c* to *d* removes the stock, while the parallel part *a* maintains the size. The small amount removed insures the durability of the tool and the smoothness of the hole. For cast iron and brass, the reamer should be entered and twisted quickly through the hole. In the case of cast iron, the use of oil is usually thought to give a smoother hole than can otherwise be

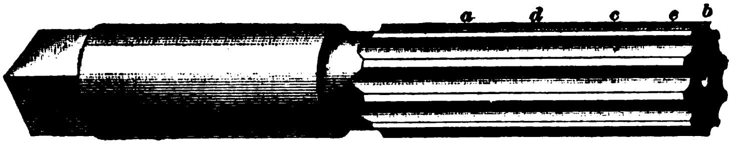


FIG. 25

obtained, although in many shops it is customary to ream dry. For wrought iron and steel, the reamer should be well lubricated with lard oil.

43. Stepped Reamer.—The reaming of taper holes, particularly large ones, in tough and hard metals, is greatly facilitated by using the stepped reamer illustrated in Fig, 26. The small end *a* of this reamer is made the size of the small end of the hole. A hole of a size corresponding to *a* is drilled into or through the work as required. The stepped reamer is then started in and run to the necessary depth. This reamer cuts only on the end of each step, as at *b*, *c*, etc., the diameter of the reamer being slightly less at the top of each step than at the lower end; for instance, the diameter is smaller at *e* than at *d*, in order that the tool may not bind in the hole. Clearance is also given the cutting edge from *f* to *g*. This reamer is cut with four flutes, and therefore has four sets of cutting edges. The half-round notches *h* are cut to make a stopping place for the wheel while grinding. The use of this reamer does away with the necessity of using a number of different-sized drills to prepare the hole for reaming. After the stepped reamer has removed the stock, a notched taper reamer is run in to remove the steps, and finally the finishing reamer smooths the hole.

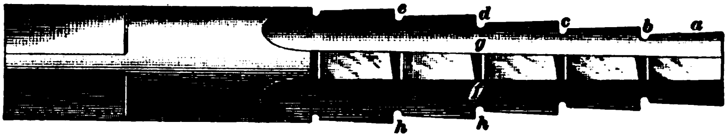


FIG. 26

44. Taper Reaming.—Taper holes are frequently hand-reamed, to make them of the correct size and smoothness. This is done after the stock is removed by the roughing and finishing reamers. The taper hand reamer, when not in use, should be kept in a box or tied up in a heavy paper covering, as any nick or dent on its cutting edges will seriously mar the hole. The reamer must also be used with great care. It should be carefully placed in the hole, well oiled if in wrought iron or steel, and turned with enough pressure to insure its cutting from the very first; turning a taper hand reamer in a hole when it does not cut will soon ruin it.

45. Advantage of Vertical Reaming.—All reaming, whether hand or machine, is better if done in a vertical position, because the weight of the reamer, if working horizontally, tends to ream downwards, and so either carries the reamer out of line or tends to take more out of the bottom side of the hole. Also, any chips or cuttings will fall out of the vertical hole, but in the horizontal hole they remain between the teeth of the reamer and often scratch or score the work.

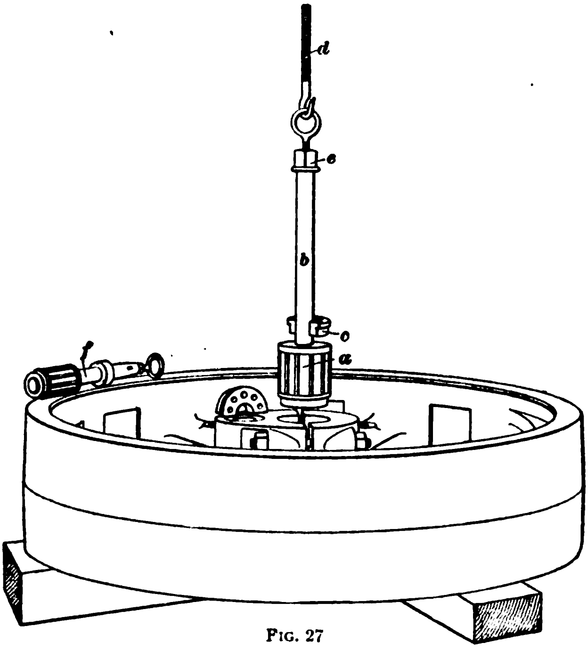


FIG. 27

46. An example of vertical reaming is illustrated in Fig. 27. The pulley shown is first put on the boring mill and turned to $\frac{1}{16}$ inch over the finished size; the hole is bored about $\frac{1}{32}$ inch small and then hand-reamed to size, after which the wheel is put on a mandrel and the face turned true and to size. The reaming is done in the following manner: The wheel is placed on blocks, as shown, and the reamer's shank *b* is passed up through the bore and hooked to the threaded rod *d*. A split bush *c* is placed around the shank *b* and pushed down into the bore to act as a guide. A double-end wrench is placed on the square of the shank at *e*, and two men walk around the wheel to turn the reamer. The threaded rod *d* passes through a nut, not shown in the cut, and this feeds the reamer *a* upwards through the hole. The reamer *a* is shown just as it leaves the finished hole. Another finishing reamer is shown at *f*.

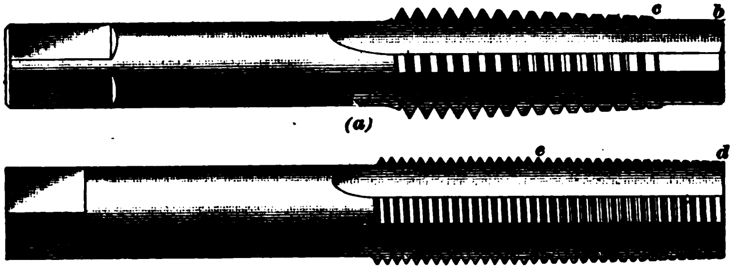
47. Reaming Holes in Line.—Holes may be reamed in line in the following manner: The holes in two or more castings that are to be bolted together are first laid out as close as possible to their correct location; all those in one piece are drilled and reamed to size, and the corresponding holes in the next piece are drilled about $\frac{1}{8}$ inch smaller; then the two castings are clamped together in their correct position, and a rose reamer, or a reamer which cuts only on its end, the same size as the finished hole, is put through the reamed part of the hole and ratcheted through the smaller hole, thus bringing them perfectly in line. This work must often be done in very contracted or limited spaces.

THREAD CUTTING

48. Methods of Tapping.—Holes are threaded in three ways: first, by cutting in the lathe; second, by using a special tapping fixture in the drilling machine; and third, by hand. The first two methods provide their own means of keeping the tap square with the work; but in hand tapping much depends on the skill of the workman.

49. Hand Tapping.—Two kinds of hand taps are in common use. The first kind, Fig. 28 (*a*), is made with a straight end *b c*, the diameter of which is equal to that at the bottom of the thread. This end fits the hole made by the tap drill, so that by the exercise of a little care on the part of the user a squarely tapped hole is the result.

The other style, Fig. 28 (*b*), is tapered from *d* to *e*; consequently, it will not stand square with the hole. To tap a hole square with the device shown in (*b*), the tap should be well oiled, placed in the hole, and turned two or three times with a double-ended wrench, which is then removed and a square applied to the tap in the manner shown at *a*, Fig. 29.



(*a*)

(*b*)

Fig. 28

Try the square at the next flute, and if the tap shows out of square apply pressure enough sidewise on it with the wrench while turning to bring it square with the surface. Repeat these trials until the tap is found to be square. If a square is not at hand, a wide 6-inch steel rule *b* may be used instead. The tap shown in Fig. 28 (*a*) will go in reasonably straight; but, for accurate work, it is better to use the same precautions as with the other style.

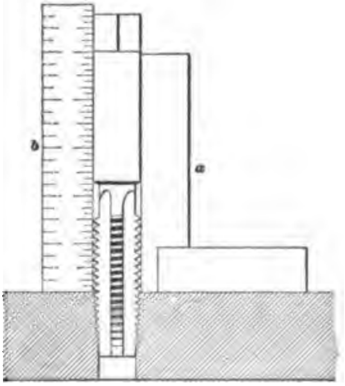
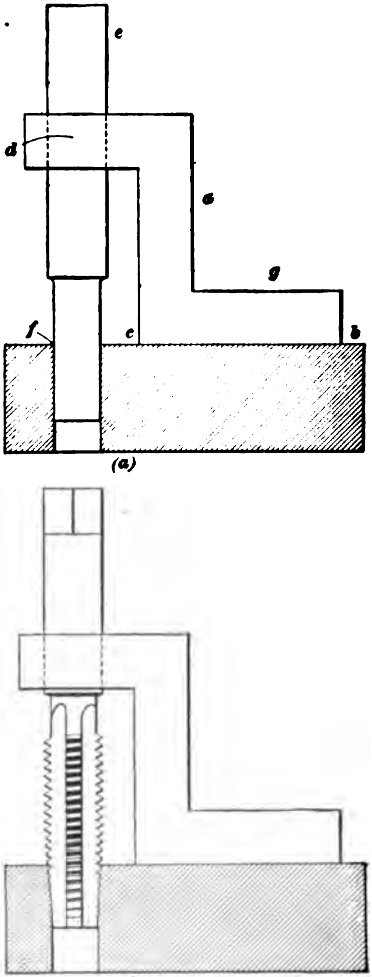


Fig. 29

50. Tapping Jig.—A tapping jig is sometimes used to guide the tap. In Fig. 30 (*a*) is shown one form of jig, consisting of a piece of iron or steel bent to the form shown at *a*. The bottom surface *b c* is planed flat, and a hole *d* the size of the tap shank is drilled square to *b c*. A plug *e* is turned to fit *d* and the hole *f* to be tapped. To use this tool or jig, the plug is put into the hole *d* and then pushed into *f*, as shown; the jig *a* is clamped fast at the point *g*, and adjusted until the plug *e* fits easily in both holes, after which the plug is removed and replaced by the tap, which will be held in the correct position to tap the hole, as shown in (*b*). The hole *d* in the jig may be made as large as the largest tap, and a set of bushings made to adjust it to taps having smaller shanks.



(a)

(b) FIG. 30

51. Tapping Smooth Threads.—It is sometimes desirable to tap holes with particularly smooth threads. In the case of United States standard threads, this may be done by first tapping the hole with a **V**-thread tap and then following it with a tap having the United States standard form of thread. The **V**-thread tap will leave enough material so that the United States standard thread tap will perform the same work in the tapped hole that the hand reamer does in the plain hole. The use of plenty of lard oil will assist in producing a smooth thread in the tapped hole.

52. Number of Taps Necessary.—Holes in thin stock may be tapped in one operation by running the taper tap clear through the piece; but if the hole is of great depth, or the material is hard, a second, or plug, tap must be run down, to relieve the long cut made by the taper tap. By using these two taps alternately, holes may be tapped to any depth that the taps will reach. Neither the taper nor the plug taps will thread a hole clear to the bottom, so when this is necessary, a third tap, called a *bottoming tap*, is screwed clear to the bottom of the hole. Care should be taken in using this tap, as the end teeth are easily broken by the heavy cut.

53. Pipe Threads.—The threads on pipe are of the **V** type; and to insure tight fits the threaded parts are made tapering. The standard taper for the threaded portion of pipe is $\frac{1}{16}$ inch to the inch or $\frac{3}{4}$ inch to the foot. The holes to be tapped for small sizes of pipe are usually drilled to the size of the bottom of the thread at the small end of the tap, and then the pipe tap is run down to the proper depth; but for the large work, a reamer having the same taper as the tap is run in to remove some of the stock. This reaming leaves the right amount of stock for threading, and saves unnecessary wear on the tap.

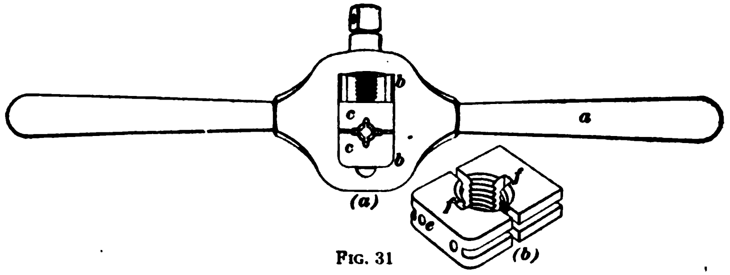
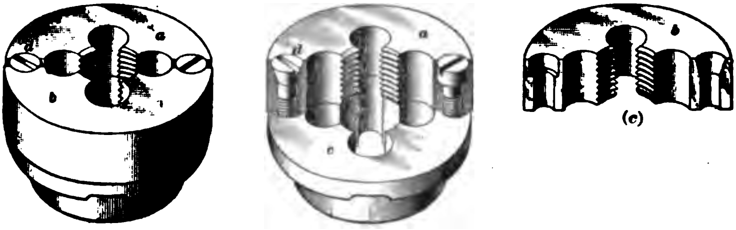


FIG. 31

Inside pipe threads are tapped a depth such that the large end of the threaded part of the standard pipe plug gauge will, when screwed into the tapped hole, be flush with the end of the fitting. Outside pipe threads are cut a depth such that one face of the standard pipe ring gauge will, when screwed onto the threaded portion, be flush with the end of the work. When standard plug-and-ring, pipe-thread gauges are not available, the pipe and fittings are threaded to fit the fittings and pipe on which they are to be used.

54. Die Stock and Square Dies.—Outside threads of various pitches and sizes must often be cut by hand. Dies for such work are made to cut threads on pieces ranging from $\frac{1}{16}$ inch to 2 inches in diameter. A form of stock and die is shown in Fig. 31 (*a*). The stock *a* has an oblong opening *b* provided with guides for holding the split die *c*, which is closed by a setscrew. The form of these dies is shown in (*b*). They are so constructed that the cutting is done at the points *f*, which also steady the dies when starting on the work. Bolts can be threaded standard, undersize, or oversize with these dies. For example, a No. 14 screw, a $\frac{1}{4}$-inch, or a $\frac{9}{32}$-inch screw, all 20 threads per inch, can be fitted with one pair of dies. They are made in several sizes and their cutting edges are provided with clearance. These dies are especially adapted to repair work where the variety of work is great and the quantity small. With them several cuts must be taken to cut a full thread. A pair of blank dies with suitable notches cut in them, used in this stock, make an excellent tap wrench.



(*a*) (*b*) (*c*)

Fig. 32

55. Die Stock and Round Dies.—Standard work is usually done with any of the many forms of round dies, one of which is illustrated in Fig. 32 (*a*), (*b*), and (*c*). When in use, the die is held in a die stock, of the form shown in Fig. 33. The die is made of two parts *a* and *b*, Fig. 32 (*a*) showing the two parts in place; (*b*), the die with one part removed, the latter being shown detached in (*c*). This die can be adjusted within narrow limits, the screw *d* being made with a tapered head, and by turning it in, the two halves are forced apart.

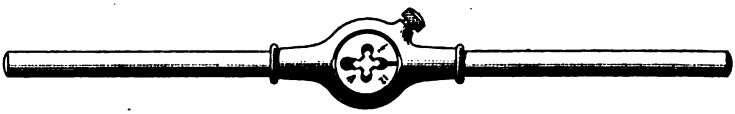
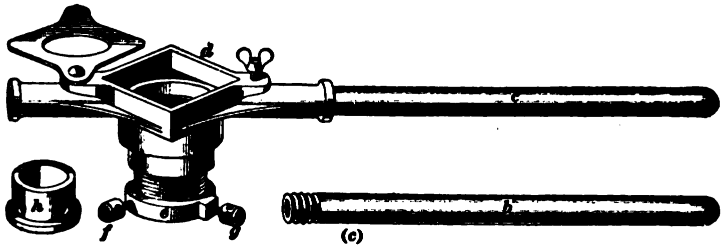
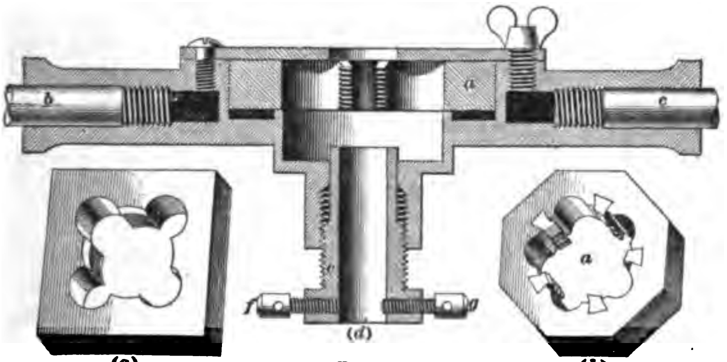


Fig. 33

56. The die stock, Fig. 33, is provided with a thumbscrew that grips the die when in place. The lower part *c*, Fig. 32 (*b*), of this die is bored out to the exact size of the rod to be threaded, and forms a guide for the die in starting. These dies require some pressure to start them; but once started they cut a full thread at one operation. The large sizes are made with inserted chasers that are adjustable for wear and if broken may easily be replaced.





(a) Fig. 34 (b)

57. Threading Pipe.—Pipework enters largely into some branches of machine work, and a few of the principal tools used in this connection will be illustrated and described. Pipe is made in lengths of from 15 to 20 feet. It is threaded on both ends at the pipe mill, and a sleeve screwed on one end. Large pipe has a ring screwed on the other end, to protect the threads during shipment and handling.

The pipe is cut to the correct length and is then ready for threading. The large sizes are usually threaded in power-driven machines, and the small sizes are done by hand with one of the various forms of pipe dies.

58. Pipe Stock.—The ordinary pipe stock is shown in Fig. 34. The die *a*, Fig. 34 (*d*), is held in the stock into whose ends the handles *b*, *c* are screwed. The stock has a square recess *d*, Fig. 34 (*c*), in the top to hold the die shown in Fig. 34 (*a*). A cover slides over the die to hold it in place. For threading the larger sizes of pipe, the pipe stock is threaded internally and the bushing, or lead screw, *e*, Fig. 34 (*d*), is screwed into it. The thread on the bushing is 11½ per inch for sizes from 1 inch up to and including 2 inches, and 8 per inch for sizes above 2 inches, to correspond to the standard pipe threads. A bushing, or thimble, *h*, Fig. 34 (*c*), having a hole through it of the size of the outside diameter of the pipe is placed in the bushing *e*, and the whole slid over the end of the pipe so that the cutting edges of the die rest on the end of the pipe. The bushing *e* is made fast to the pipe by the setscrews *f* and *g*, which pass through the holes in the thimble *h*, and the stock is given a few turns to start the die on the pipe, the screw thread in the stock acting the same as the lead screw in a lathe. As soon as the die has a good start, the setscrews holding the feed-screw may be loosened, and the work finished without using the feed-screw further. The small sizes of pipe are threaded in the same manner, but the die stock is made without the feed or lead screw.

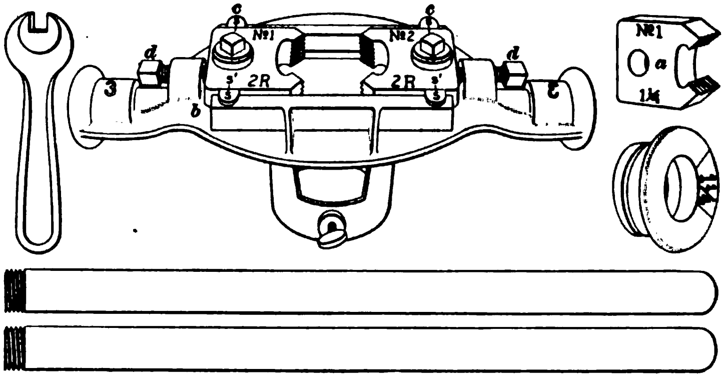


FIG. 35

59. Adjustable Pipe Dies.—An adjustable die, made in two parts, is shown in Fig. 35. The stock is provided with the usual handles for turning and the thimble for guiding the dies on the pipe. The dies *a* are held in the stock *b* by means of the clamp screws *c*, and are made to cut larger or smaller than the standard by the adjusting screws *d*. Lines *s* are cut in the stock, and corresponding lines *s'* are placed on each die, so that when these lines coincide the dies are set to cut pipe to the standard size. As these dies are more easily sharpened, they are considered decidedly superior to the solid ones.

LAYING OUT

PRINCIPLES

60. Laying out is the process of placing such lines on castings, forgings, or partly finished surfaces as will designate the exact location and nature of the operations specified in the drawing.

61. Preliminary Layout.—In many cases, one or more men are regularly employed in laying out work. Occasionally, the same men devote a part of their time to inspecting or testing finished or partly finished work. The inspection when partly finished is to prevent additional work, should the first operation be so defective as to call for the rejection of the piece. When the work is laid out by an expert who has the drawing of the finished piece before him, he may determine, before any work is done, whether the forging or casting has sufficient stock, and should stock be lacking at any particular point, the piece may either be rejected or perhaps saved by carefully locating the lines so as to permit the finishing of all the holes and surfaces; whereas, without the special laying out, it may afterwards be found that there is not sufficient stock for some later operation.

62. The economy of having the laying out done by men set apart for that purpose is due to several reasons. Men become expert and quick at this kind of work; the tools of the shop are not idle while the men running them stop the machine to do the laying out, as was formerly the case; and the work can be laid out on a convenient plate with proper tools to better advantage than otherwise. Then, work can be laid out as soon as the castings or forgings come into the shop, perhaps long before the tools are at liberty to finish the work, and it may be of great advantage to find out early any lack of stock, or any defect that may cause the rejection of the piece, or any change that is to be made, if it is a forging. A casting may appear perfect, but a hole may be cored too large, or the core may not have been set correctly, or it may have moved in the mold. After laying out some of the lines and making sure that there is stock enough for finishing, it is often advisable to do part of the finishing before completing the laying out.

63. **Divisions of Laying Out.**—Laying out may be divided into two parts: the preliminary and the final. The preliminary laying out consists in measuring the piece to see that it is of the proper size and dimensions, and then drawing such lines on its surface as will show where the first machining operations are to be performed. The center lines are so placed, if possible, that they will not be removed by the machining process, and can be used in resetting the piece for future machining. In the final laying out such lines are placed on the machined surfaces as will indicate the further operations to be performed.

The preliminary laying out in the case of a steam-chest cover would be to level it on the table and draw such lines on its edges as will indicate its thickness; after which it should go to the planer and be machined to the dimensions denoted by the lines. The final laying out will consist of laying out the holes for the studs and such other operations as may be designated on the drawing.

64. **Methods of Laying Out.**—Laying out is done in different ways, according to the nature of the work and the accuracy required. The lines are drawn on the surfaces with surface gauges or scribers, and centers are denoted by prick-

punch marks. Circles and arcs of circles are drawn with dividers and trammels, and many irregular forms are drawn on the work from accurately filed templets.

In some cases, the work is laid out by simply drawing the necessary lines on its surface. In other instances, permanence is given the lines by dotting them with prick-punch marks placed directly on the line; or a thin chisel may be driven into the work on the lines, making a deep cut in the metal. Guard lines are often placed on the work to make sure that the original lines were closely followed, as, in laying out holes to be drilled, some machinists place a circle $\frac{1}{16}$ inch outside the one worked to, and if the hole is correctly drilled, it will be concentric with this circle.

65. Coatings on Which to Make Lines.—In many cases it would be impossible to scratch lines on an iron surface, especially when the surface is either not perfectly smooth or it is very hard. The use of various coatings, on which the lines may be made or in which they may be scratched is therefore necessary. Sometimes, chalk is simply rubbed on the surface. In other cases, powdered chalk is mixed with alcohol, or whiting is mixed with alcohol or water, and applied with a brush. Alcohol has the advantage over water in that it will dry quicker and has no tendency to rust the surface.

66. When the surface has been machined and is fairly smooth, it may be copper-plated by wetting and rubbing with a piece of copper sulphate (blue vitriol), or, better still, by making a saturated solution of copper sulphate and applying with a brush or swab. As the solution dries, the surface will be covered with a thin layer of copper. Surfaces to be thus coppered must be thoroughly cleaned and free from oil before applying the solution. Lines may easily be scratched in this copper and will show very plainly on account of the difference in color between the iron and the copper. A light coat of some quick-drying white paint is sometimes used, as, for instance, white lead and turpentine. After the lines are drawn, their location should be permanently established by means of light prick-punch marks.

LAYING-OUT TOOLS

67. A variety of tools are used in laying out work. The most common are the surface gauge, straightedge, scriber, hammer, prick punch, level, square, dividers, trammels, and a line, if large work is handled. In addition to these tools, there should be a supply of quick-drying white paint, chalk, a solution of blue vitriol, a lot of iron wedges, and small pieces of sheet metal of various thicknesses for blocking, parallels of various sizes, small screw jacks, one or more pairs of V blocks, a pinch bar, and a hack saw.

The surface of the laying-out table or plate must be kept as clean as possible; therefore, a bench brush should be provided for the table, and for the large plate, a brush and broom. As a good many drawings are used at the laying-out table, a table or stand of sufficient size to hold them, and drawers in which to place those not in constant use, should be provided near at hand.

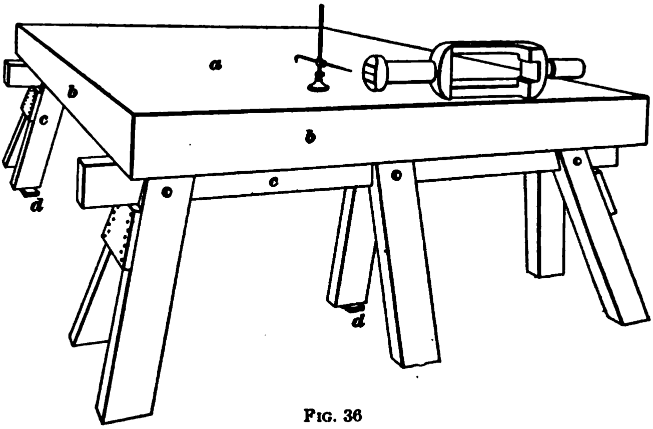


FIG. 36

68. Laying-Out Plate for Light Work.—For laying out light or small work, the size and character of the plate used may vary greatly. Fig. 36 illustrates a general form of laying-out plate. The plate *a* may vary in size from 2 or 3 feet on each side up, about 7 feet by 10 feet being the largest size practicable for this design of plate. In the larger size, the top *a* should be made 1¼ inches thick, the ribs *b* should be carried around the sides of the plate, and cross-ribs placed across the back of the plate about every 24 inches; the depth of these ribs for a plate 7 feet by 10 feet should not be less than 8 inches, and they should be of the same thickness as the body of the plate. The casting should be planed on the upper surface *a* and on the faces of the ribs *b*, so that the faces *b* will be at right angles to the surface *a*, thus making it possible to use surface gauges or other tools from the faces *b*. Parallel lines should be drawn both lengthwise and crosswise of the plate, the lines being 3 or 6 inches apart. The plate is mounted on trestles *c*, and the upper surface of the plate should be kept level and out of wind, by adjusting wedges under the legs of the trestles, as shown at *d*. For ordinary working, the upper surface of the plate should be about 30 inches from the floor. Such a plate as this may be placed under the main traveling crane, and it is also well to have an auxiliary air lift, or similar hoisting device, for handling the work when the crane is not available.

69. The advantages of this style of plate are that it is not a permanent fixture, but can be easily moved from one part of the shop to another. Then, too, if the plate is not needed for some time, but the floor space is, the plate can be turned up on one edge and set against the wall.

The disadvantages are that owing to its support on trestles it is not suitable for laying off heavy work that requires great accuracy, owing to the fact that the plate cannot be kept true and out of wind when heavy weights are being placed on or taken from it, as the stresses on both the plate and the trestles are constantly changing. A plate of this general style is sometimes mounted on a concrete or brick foundation; but if this expense is to be incurred, it is usually best to have a more elaborate plate, such as is described in Arts. **70** and **71.**

70. Laying-Out Plate for Heavy Work.—For laying out heavy work, the plate must have a very firm foundation, and the ribs must be of such a depth that the plate will not spring under the weight of the piece being laid out. Plates

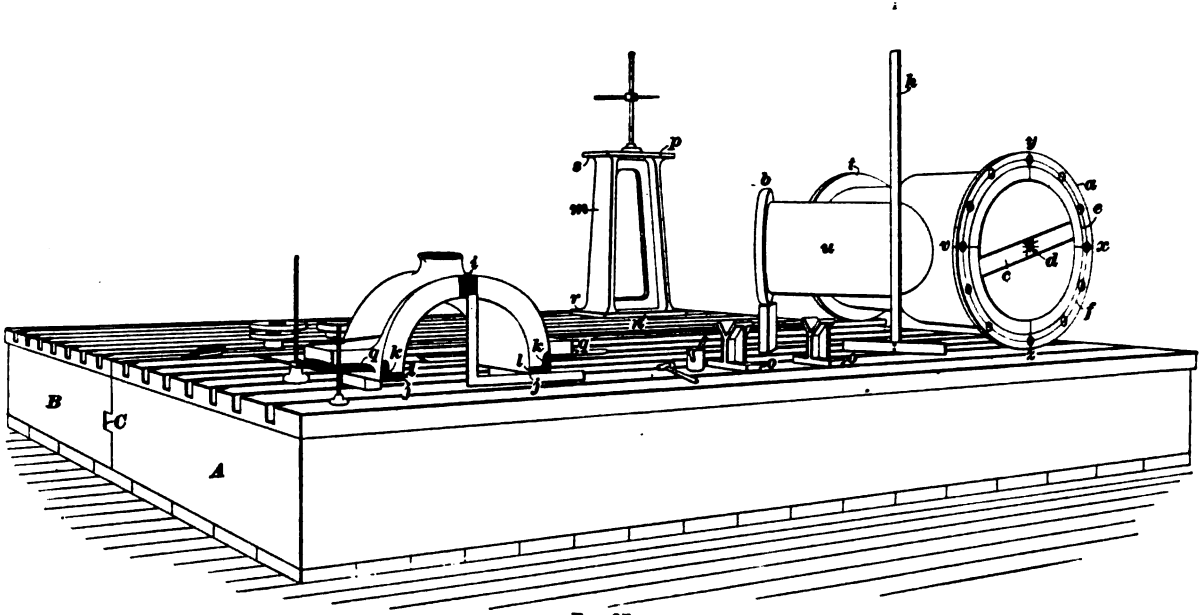


Fig. 37

for heavy work are usually made lower than those for light work, the top of the plate being placed from 18 to 24 inches above the floor. Fig. 37 illustrates a very good plate for heavy work. The top of this plate is 24 inches above the floor, and it is composed of two pieces *A* and *B* that are joined with a tongue and groove, as shown at *C*. This plate is 8 feet by 15 feet, and the ribs around the outside and along the center are made to extend clear to the foundation, which is only 2 inches above the floor, thus making the plate 22 inches deep. Parallel grooves 6 inches apart are planed the entire length of the top surface, and at right angles to these grooves, lines are ruled on the surface 6 inches apart. The grooves are especially handy, because parallels can be slipped into them and pieces brought against these parallels for lining up, after which measurements may be made from either grooves or lines. All heavy plates should have a good bearing on the foundation, which should be made so deep and strong that it will not settle or be broken under any weight that is liable to be put on the plate.

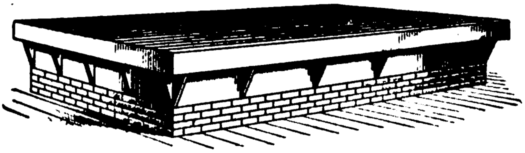


FIG. 38

71. Laying-Out Plate for General Work.—In shops handling a variety of work, varying from heavy to light, a plate of the form illustrated in Fig. 38 may be used. This plate is about 8 feet by 12 feet. The foundation consists of a concrete base, Fig. 39, on which are built three brick walls running lengthwise of the plate and a cross-wall at each end. The plate is supported on these walls, as shown in Fig. 39. A hole in the plate, at least 18 inches by 24 inches, together with an opening in the middle wall, affords access to the space beneath the plate for the purpose of cementing between the iron and brickwork. This hole in the plate is also useful, because it permits parts of the work to hang below the surface; as, for instance, one crank of a three-throw crank, or an arm on a rocker-shaft.

The hole is cast with a ledge to receive a wooden cover, which prevents objects from falling through the hole and being lost under the plate. The top of the wooden cover should be ⅛ inch below the surface of the plate. The plate overhangs the foundation 7 inches all around, to allow foot-room on the floor.

72. Grooves ½ inch wide and ¼ inch deep are planed lengthwise every 6 inches, and lines made crosswise every 6 inches; or grooves may be planed both lengthwise and crosswise. A number of short parallels ½-inch square should be provided to drop into the grooves to aid in locating the work or tools.

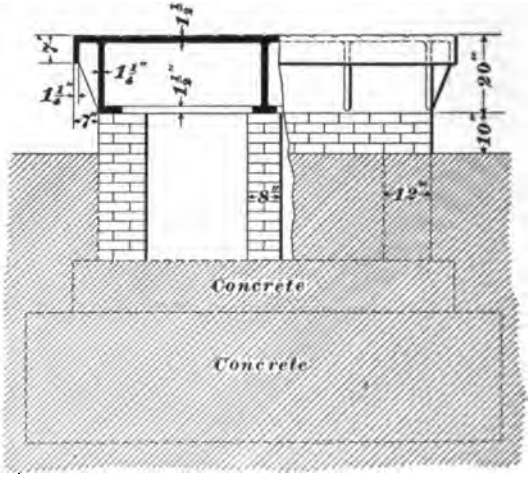


Fig. 39

The proportions or size of the plate may be varied to suit the character of the work being done. It is not good practice to mount a plate on brick walls all running in one direction, when heavy work is to be placed on or taken off the plate; for if work were to strike the end, there would be danger of racking the walls, while the tying of the longitudinal walls together at the ends tends to overcome this difficulty, and also prevents dirt from collecting beneath the plate.

73. Revolving Laying-Out Plate.—In many cases the light must fall on the work from a certain direction, to enable the operator to see the lines being drawn; also, in the case of small work, it is often necessary to operate on several sides of the piece. If placed on a large plate, this work would have to be turned and reset several times, or the operator would have to climb over the plate. To overcome this difficulty, a revolving plate of the general form shown in Fig. 40 may be used.

74. This plate consists of a circular table *a* mounted on a suitable foot, or base, *b*. The back of the plate *a* is ribbed, as shown in Fig. 41, and a ball bearing is inserted between the plate *a* and the base *b*, as shown at *c*. To facilitate the centering of work having a hole in it, a plug *d*, Fig. 40, may be inserted in the center of the table and a ring *e* of suitable diameter placed over the plug. Work thus dropped over a ring of the proper size can be quickly centered. To facilitate the dividing of

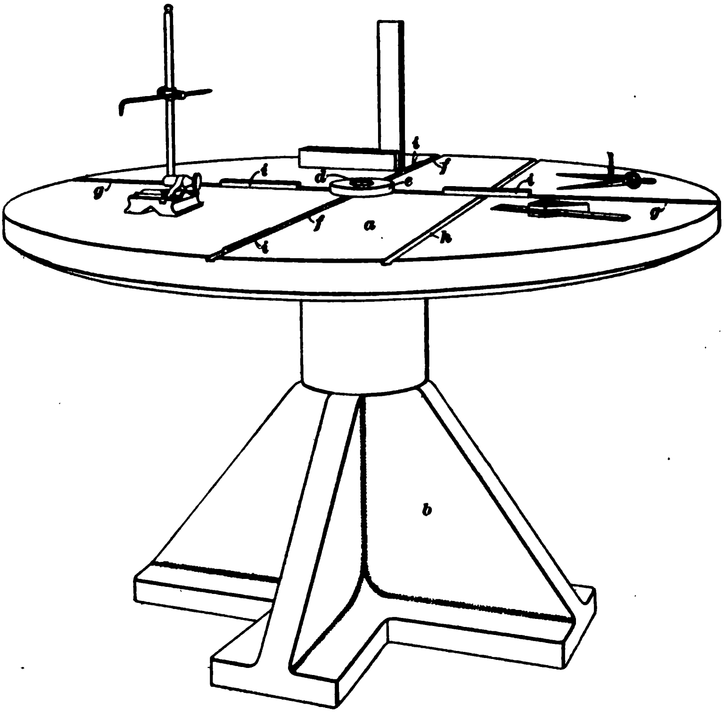


FIG. 40

work, two grooves *f* and *g* are planed across the table at right angles. One edge of each groove passes through the center of the table. For convenience in measuring, other grooves may be located at any specified distance from the center, and parallel to either one of the main grooves, as shown at *h*. Small parallels are frequently inserted into the grooves when setting squares or other tools, or as a stop to locate the work in the desired position. These parallels are shown in position at *i*.

75. The top of the table illustrated is 31 inches above the floor, and the rim is 2 inches thick. For some classes of work it is convenient to have circular lines, 1 inch apart, turned on the table before the plate is taken from the lathe. This form of table can be easily taken to the work, in place of bringing the work to the table, in cases where there is a large amount to be handled, and especially when it is advantageous to have it done near the same machine. For convenience in moving the table, an extension of the hole that receives the pin *d* in the base *b* may be tapped, and a strong eyebolt fitted to it. This bolt will form a ready means of attaching the crane hook to the table.

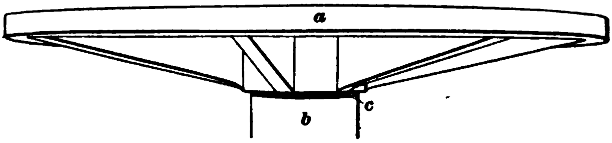


FIG. 41

76. Special Laying-Out Appliances.—On the laying-out table illustrated in Fig. 37 are shown several special laying-out appliances. First may be mentioned the parallel shown at *m*. These parallels are made in various heights, differing by even feet, and smaller solid parallels or hollow rectangular parallels are made, varying by inches, so that any height varying by inches can be obtained from a series of them. The edges *n* and *p*, and *r* and *s* should be in the same vertical planes, so that when one of the edges *n* or *r* is brought against a certain parallel or line on the plate, the corresponding edge *p* or *s* will be in the same vertical plane. The man doing the work is thus enabled to obtain horizontal measurements from the edges of the upper surfaces of the parallels. With the use of these parallels, it is unnecessary to use the old-fashioned high surface gauge, which could never be depended on because of the spring of its parts.

77. At the front of the plate are shown two **V** blocks *o* that are extremely useful in laying out pieces having turned ends, or any form that must be supported in this manner. At *h* is shown a special **T** square, which, for some classes of work, is more useful than an ordinary square for drawing vertical lines, owing to the fact that there is little, if any, danger of the portion in contact with the plate becoming displaced; while if an ordinary square were used, the arm or beam in contact with the plate must be made very heavy to balance the long blade.

EXAMPLES OF LAYING OUT

78. Locating Centers of Circles.—When it is necessary to draw a circle, the center of which falls in an opening or cored hole, a strip of wood, or other material, must be fitted across the opening, and the center located on it. As wood is too soft to give a good center to work from, it is usual to place a piece of metal on it where the center is required. This piece of metal may be a tack driven into the wood, the center being located on the head; or a triangular piece of tin having the corners bent at right angles to the surface, so that they can be driven into the wood, the center being located on the flat surface of the tin.

79. Use of Screw Jacks.—Small screw jacks having flat sides on the body of the jack are sometimes used to locate centers, the screw jack being placed across the hole and the center located on its side, as shown in Fig. 42 (*a*). After the center is located, the bolt-hole circle is drawn, and the required holes spaced off on it. If the cored hole is too large for one screw jack to reach across, two screw jacks may be placed with their bases together, as shown in (*b*), and the center located on them.

80. Laying Off Subdivisions of Circle.—When a circle is to be divided into 4 or 6 parts, or into multiples of 4 or 6 parts, it is usual to draw diameters dividing it into this number of parts first, and then make any additional subdivisions from these points. Four divisions can be easily obtained by drawing two diameters at right angles, the work being mounted on the laying-out plate, the horizontal diameter being obtained with the surface gauge, and the vertical one by means of a square.

81. To lay off six divisions, set the dividers equal to the radius of the circle and then step them around the circumference of the circle, when it will be found that the radius will make six equal divisions. To determine the dimension to which the dividers must be set to lay off any other number of divisions, up to and including 100, Table I is given. By its use, the dividers may be set very closely, and much of the time and trouble usually spent in getting the dividers properly set by stepping them around with trial distances may be avoided. The numbers in the column headed N indicate the number of divisions into which the circle is to be divided, and the numbers in the column headed S are the factors that, when multiplied by the diameter, expressed in inches, of the circle to be divided give the measurement to which the dividers must be set to lay off the required number of subdivisions of the circle.

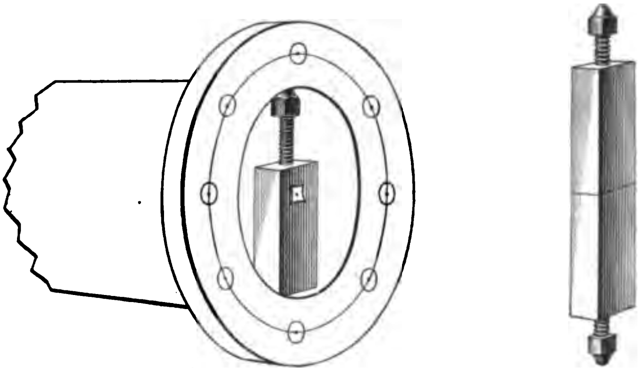

(a) (b)

FIG. 42

Example.—If it is required to divide a 62-inch circle into 44 equal parts; what will be the distance to which the dividers should be set?

TABLE I

FACTORS FOR FINDING DIMENSIONS FOR DIVIDING CIRCLES

N	S	N	S	N	S	N	S
1		26	.120540	51	.061560	76	.041325
2		27	.116090	52	.060379	77	.040788
3	.86603	28	.111970	53	.059240	78	.040267
4	.70711	29	.108120	54	.058145	79	.039757
5	.58779	30	.104530	55	.057090	80	.039260
6	.50000	31	.101170	56	.056071	81	.038775
7	.43388	32	.098018	57	.055089	82	.038303
8	.38268	33	.095056	58	.054139	83	.037841
9	.34202	34	.092269	59	.053222	84	.037391
10	.30902	35	.089640	60	.052336	85	.036953
11	.28173	36	.087156	61	.051478	86	.036522
12	.25882	37	.084804	62	.050649	87	.036103
13	.23932	38	.082580	63	.049845	88	.035692
14	.22252	39	.080466	64	.049068	89	.035291
15	.20791	40	.078460	65	.048312	90	.034899
16	.19509	41	.076549	66	.047582	91	.034516
17	.18375	42	.074731	67	.046872	92	.034141
18	.17365	43	.072995	68	.046184	93	.033774
19	.16460	44	.071339	69	.045515	94	.033415
20	.15643	45	.069756	70	.044865	95	.033064
21	.14904	46	.068243	71	.044232	96	.032719
22	.14232	47	.066793	72	.043619	97	.032381
23	.13617	48	.065401	73	.043022	98	.032051
24	.13053	49	.064073	74	.042441	99	.031728
25	.12533	50	.062791	75	.041875	100	.031411

Solution.—Opposite 44 in the column marked N of the table, and in the column marked S, is found .071339. Multiplying this factor by the diameter of the circle, the required distance is found to be

$$.071339 \times 62 = 4.423018 \text{ in.} \quad \text{Ans.}$$

For ordinary work it would not be necessary to set the dividers closer than to hundredths of an inch; hence, the dividers may be set to 4.42 inches. Since 44 is divisible by 4, the circle may be divided by two diameters drawn at right angles, and the spaces marked off from the four points thus obtained.

82. Reducing Error When Subdividing Circles.—It is always best in laying off divisions of a circle to locate either 4 or 6 points accurately, when possible, and to work from these, as this reduces the effect produced by means of a slight mistake in the setting of the dividers; for if the circle were all laid off from one point, and the dividers were set to a distance slightly greater than that required, the last division would be smaller than the others by an amount equal to this error multiplied by the whole number of spaces in the circle. But by dividing the circle into 4 or 6 parts, and then stepping off the spaces each way from each of these points, the total error at any given point will only amount to the error in setting the dividers multiplied by the number of spaces marked off from the given point.

83. Laying Out Bolt Holes for Pipe Flanges.—In Fig. 37 at the right-hand side of the plate is shown a casting for a branch pipe in which it is required to lay out bolt holes for the different flanges. The pipe is leveled by blocking up the small end *t* until the large end *a* stands square with the plate or table. The branch, or arm, *u* is next raised until the surface *b* is square with the table. Wooden strips are fitted across the ends of the pipe, as shown at *c*, this fitting usually being done before leveling up the pipe, so as not to displace the setting by driving in the wooden strips. After the wooden strips are in place and the pipe is leveled up, the trammels are set to approximately the radius of the circle *e* that has been turned on the end of the pipe while in the machine. With these trammels, the arcs at *d* are drawn and a center located between them. Usually, a small piece of tin or other metal is placed at the center of the wooden strip, to receive the center when located. After this, the trammels or dividers are set to the radius of the bolt circle *f* and this circle is drawn.

84. If the drawing calls for an even number of holes, a surface gauge is set to the center and a line drawn across the flange, as shown at *v x*. This line may be continued across all three of the flanges. If the number of holes is a multiple of 4, a vertical line is also drawn by means of a square, or a T square similar to that shown at *h*, thus locating the top and bottom holes *y* and *z*. The other holes are spaced off from these by means of dividers. In case of any number of holes, whether odd or even, the setting of the dividers can be obtained by the method described in Art. **81.** In Fig. 37, 12 holes are shown in the flange *a*. When the holes in the three flanges must have some fixed relation to one another, the horizontal line *v x* is carried around all three faces, and the holes laid off from this as required.

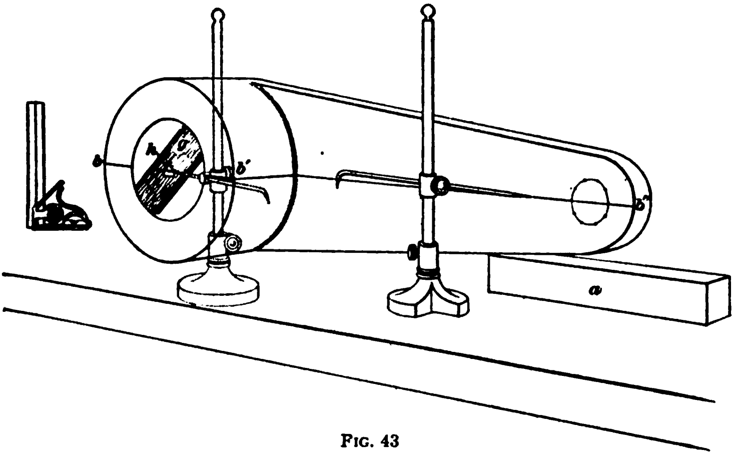


FIG. 43

85. **Laying Out Large Journal Cap.**—At the left-hand corner of the plate, Fig. 37, is shown a journal cap in the process of being laid out. The casting is blocked up on the plate so that the front and back faces are approximately square to the surface, and the center line *i* is drawn midway between the points *j*. The shoulders *k* are laid off at equal distances from the center line *i*, and a proper allowance for finish is made at the top of the bearing, after which the lines *l* are drawn, so that the vertical distance from the horizontal plane passing through *l* to the point determined at the top of the bearing is equal to the radius of the finished bearing. The lines *q* on the flanges of the cap are next drawn the proper distance above the lines *l*. After this, the cap is planed before the holes for bolting down the cap are laid out or drilled.

86. Laying Out Crank-Arm.—The crank-arm shown in Fig. 43 may be laid out as follows: The piece is first placed on its side, with the parallel *a* under the small end. A surface gauge is set to the center of the hub, which has been determined by placing a wooden strip *g* across the hub and locating a center *h* on it by means of dividers. After this, the parallel *a* is pushed under the end of the arm until the small end is raised so that the point of the dividers is level with the center of the arm. Then the line *b b′ b″* is drawn. After this the arm is clamped to an angle plate, as shown in Fig. 44, the line *b b′* being brought vertical by means of a square. The surface gauge is set to the center *h* and the line *c c′* drawn. Substitut-

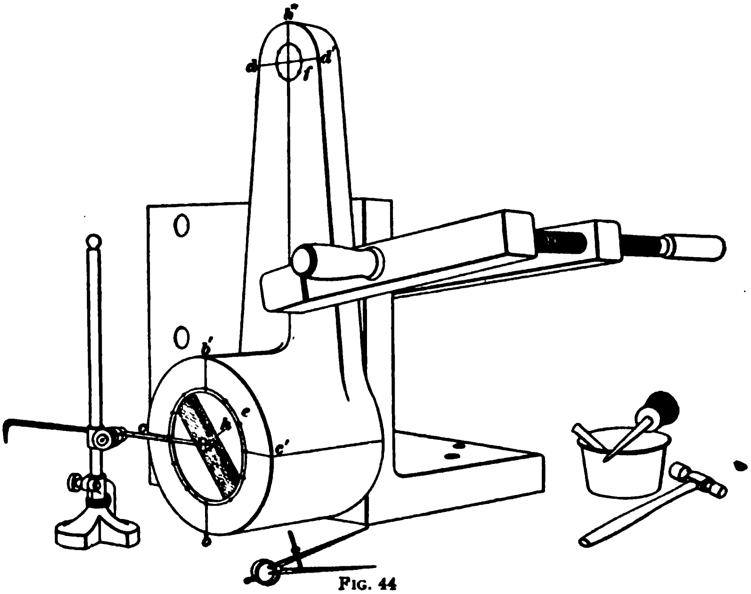


FIG. 44

ing a longer spindle in the surface gauge, it is next set so that its point will be above the line *c c′* an amount equal to the distance between the two holes in the arm, and the line *d d′* is drawn. This locates the center of the hole *f*, after which the circles at *e* and *f* may be drawn with dividers and marked off with prick-punch marks, as shown, ready for drilling or boring.

87. Laying Out Crosshead.—The method of laying out a crosshead is governed principally by the design of the crosshead. The form shown in Fig. 45 is one provided with adjustable shoes, the end *h h′* of the crosshead being considerably narrower than the end *a a′*, so that as the shoes are moved along on these inclined surfaces they will be expanded. The method of laying out is as follows: The crosshead is placed on the table, with blocking under the piston-rod end, and wedges under both sides of the connecting-rod end, as shown in the illustration. If the piston-rod end is to be turned at the part marked *d*, the casting is usually made with a metal bridge *f*, which is cut out after the rest of the machine work has been done. If no such metal bridge exists, a wooden strip must be inserted at this point on which to locate the center *f*. Wooden blocks are also placed in the holes, as shown at *e*, and in the center of the piston-rod hole in the end *d*.

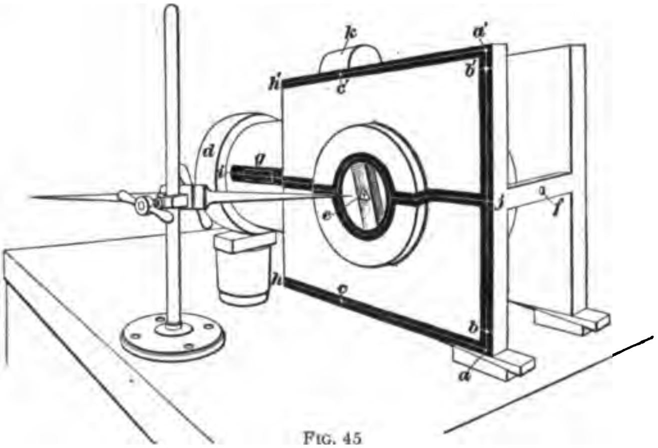


FIG. 45

88. Chalk or white paint is applied in a broad line wherever the laying-off lines are to be placed, as shown by the broad, dark marks in the illustration. The centers of the holes for the connecting-rod pin and for the piston rod are now found, and the casting is leveled up by them and brought square with the table at the connecting-rod end. If the cored holes for the piston-rod or crosshead pin are not in the correct relative position, the body of the casting may be shifted somewhat, to bring them into such a location that all can be finished to the required dimensions. When these points are definitely located, the center line *i j* is drawn on all sides of the work. The centers at each end of the crosshead pinholes *e* are laid off the proper distance from the piston-rod end *d*, and a circle is drawn at each end of the crosshead pinhole. A circle is also drawn for the piston-rod hole. The slot *g* for the piston-rod key is next laid off the proper distance from the end *d*. This slot is sometimes made with round ends and sometimes with square ends, depending on the conditions specified in the drawing.

89. The line $a\,a'$ is drawn the correct distance from the center *e*, this line being located by means of a square that is set on the table. The lines $a\,h$ and $a'\,h'$ are not parallel to the table, on account of the tapered form of the crosshead body, and in order to determine these lines, the following process may be used: The taper is usually given as so much per foot on the drawing, and this amount may be marked off from *a* and a', as shown at *b* and b'. After this, short vertical lines are located at *c* and c', 1 foot from the line $a\,a'$, and the surface gauge is set to the point *b*, and a mark made at *c*. It is then set to b', and a mark made at c', thus establishing two points on the inclined lines. After this a straightedge may be laid through the points *a* and *c* and the line $a\,h$ drawn, and then through the points a', c' and the line $a'\,h'$ drawn. The lugs *k* must be drilled for screws to operate the crosshead shoes. These screw holes may be located by drawing horizontal lines on the piston-rod end of the lugs by means of the surface gauge. These lines must be the proper distance from the center line of the crosshead. After this, the center of the lugs may be found by means of dividers, and the circles representing the holes laid out.

90. Laying Out Engine Bed.—The method of laying out an engine bed differs according to the type of bed, but the essential features of the process are the same. Usually, the work has to be done in two or three operations, as some of the surfaces must be machined before the last part of the laying out can be done.

The bed chosen for illustration is shown in Fig. 46, and is of the solid cast type, having bored guides, the bearing for the crank-shaft being cast solid with the bed and the cylinder being arranged to bolt to the end of the bed. The bed casting *a* is placed on the laying-out or machine table, right side up, with blocks under it at intervals, as shown at *b*, *b*. Wooden strips are fitted across the ends of the guides, as shown at *r*, and across the sides of the jaws for the crank-shaft bearing, as shown at *c*. The centers of the guides are located on the wooden strips at both ends, and those of the jaws at both sides. The bed is now tested with the surface gauge, and set level by driving wedges between the bed and the blocks *b*. If either of the points located does not come true, the centers may be shifted slightly, care being taken to allow stock enough so that the guides and the jaws of the main bearing can be finished. Some beds of this type have their bottoms planed. If the bottom is not to be planed, it should be left as nearly parallel with the center line *d d* as possible. After having adjusted the centers of the guides and the jaws so that they all come level, and so that there is sufficient stock for finishing these parts, a surface gauge is set to the height of the center of the guides, and the line *d d* is drawn on painted strips or spots on both sides and ends of the casting. If the bottom is to be planed, the line *f f* should be drawn parallel to *d d*, and at the proper distance from it. After this, circles are drawn on the ends of the guides, using the centers in the blocks *r*. These blocks are then removed, and either a piece of piano wire or a sea-grass fish line *e e* is stretched through the guides. Each end of this

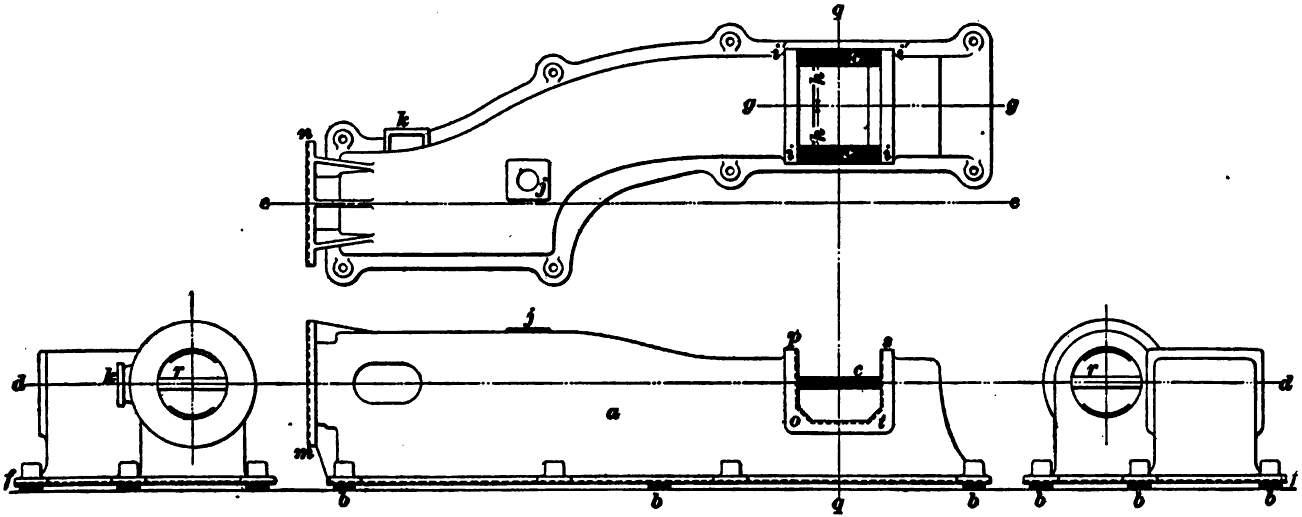


FIG. 46

line is secured to an upright and adjusted until it is located centrally with the circles scribed on the ends of the guides. The distance from this line *e e* to the center of the crank-shaft bearing is obtained from the drawing. A square is then brought against the line *e e*, and measuring from the square, the line *g g* is marked on the top of the jaws of the bearing. The distances *h* are obtained from the drawing, and the lines *i i* and *i′ i′* are drawn so as to determine the amount of stock to be removed from each end of the bearing.

91. The height of the governor pad from the bottom of the bedplate is marked off at *j*, and the amount to be removed from the rocker-arm hub is laid off at *k*. After this, the end of the bed to which the cylinder is to be bolted is also laid off, the line *m n* being drawn, thus determining the amount to be faced from this end. The distance from the end of this face to the center of the bearing should agree with the drawing. Most of the faces already determined must now be machined, after which the lines *o p*, *s t*, and *o t* may be laid off on the jaws of the bearing, and the center of the rocker-shaft hub at *k* may be laid off the proper distance below the center line. After the guides are bored and the end faced off to the line *m n*, the bolt circle may be drawn on this end, and the bolt holes laid out in a manner similar to that described for the laying out of bolts and flanges in Art. **83.**

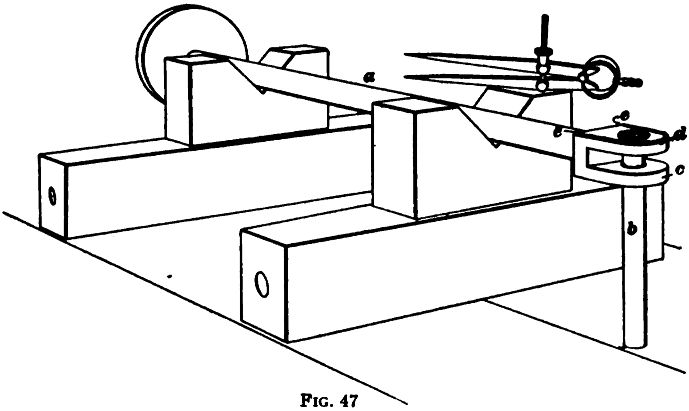


FIG. 47

If the laying out is done on a table having lines running both lengthwise and crosswise, it will simplify matters to adjust the bed so that some one line corresponds with the center line *e e*, after which many of the measurements may be obtained from the other lines.

92. Laying Out Ends for Small Rods.—A convenient method of laying out the ends of small rods is shown in Fig. 47, where the piston rod *a* is placed on V blocks that bring it level. A stake or post *b* is put into a hole in the plate or table, to which it has been fitted, so that it stands perpendicular, as shown, with its upper end through the holes in the fork *c*, fitting it accurately. The top end of the post *b* has a small center-punch mark in it, which provides a convenient center from which to draw the circle *d* for the rounded end of the fork. After the fork has been revolved to a vertical position and set to a square, the parallel edge lines from *e* tangent to this circle are drawn by means of a surface gauge.

ERECTING

(PART 1)

ERECTING TOOLS AND APPLIANCES

INTRODUCTION

1. **Erecting** is the putting together, assembling, or building of a whole from its parts. It refers to any mechanism or apparatus of appreciable size, such as an engine, dynamo, machine, or other mechanical device commonly used in the various engineering industries. It may be said to be divided into two classes: *shop* and *field erecting.*

2. On the completion of the parts of any mechanism, it is customary to assemble these together in the shop where they have been built, in order to test the device as a whole. When such shop tests have been satisfactorily carried out, the mechanism is next usually disassembled into parts or units of convenient size and packed ready for transportation to its destination. This first assembly is called **shop erecting.**

3. After arrival at its destination, the several parts or units are once more assembled or erected as a whole, the mechanism, however, being placed this time in its final working position; it is again tested, and, if the conditions of the contract have been met, is delivered to the purchaser. This second assembly is called **field erecting.**

The parts forming the complete mechanism are sometimes shipped direct to their destination without first being assembled and tested in the shop where built. When this is done, however,

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it is usually owing to extraordinary conditions, such as lack of time in the fulfilment of a contract, inadequate assembling or testing facilities, too great expense, or to duplicate apparatus having already been built so that there is full assurance that all parts will go together without any preliminary fitting or adjusting.

4. The tools and appliances used in erecting are those employed in bench, vise, and floor work, together with pinch bars, rollers, blocking devices, hoists, trucks, etc.

PINCH BARS, ROLLERS, AND BLOCKING DEVICES

PINCH BARS AND ROLLERS

5. A **pinch bar** is an iron or steel bar used to pry up or move heavy objects. The most common form of pinch bar, Fig. 1 (*a*), is a straight bar, one end of which has a flat, wedge-shaped point turned slightly to one side, and the other end of which is round and slightly tapering to form a handle. This form of bar is usually about 4 to 6 feet long. The smaller pinch bars are from 2 to 4 feet long, and are made of ⅝-inch or ¾-inch octagonal steel, as shown at (*b*).

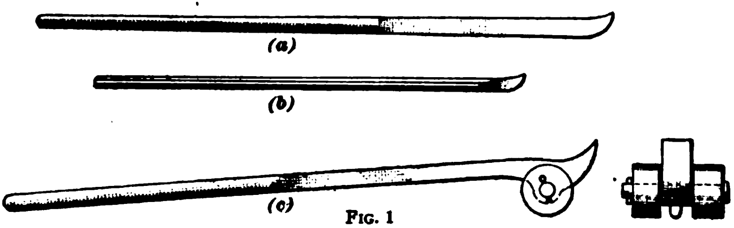


FIG. 1

A rather convenient form of pinch bar that is well adapted for lifting and moving quite heavy weights is illustrated in Fig. 1 (*c*). The bar is mounted on two wheels, and consequently, when it supports a heavy weight, the bar and weight can be easily shifted.

6. **Rollers** are cylinders, either of wood or metal, and of various diameters and lengths, which are placed under a piece of apparatus, thus enabling it to be readily moved for short distances. When metal rollers are used and the weight of the apparatus is not too great, they are generally made of pipe, not only because they are lighter and cheaper in cost, but also because they are more easily kept in alinement when in use either by inserting a bar and moving them, or by hitting them with a sledge.

BLOCKS AND TRESTLES

7. Any material or device employed in temporarily supporting work in process of erection, is known as *blocking*. The purpose of such supports is either to aline the work in some particular manner, to raise it into a certain position, or to move it in a given direction so that the assembling or erecting may be the more readily accomplished.

The form of the blocking depends on the class of work on which it is used and the service it is intended to perform. Frequently both the simplest and the most elaborate blocking devices are used advantageously on the same piece of work. Among the simpler forms may be mentioned *wooden blocks*, *iron blocks*, and *trestles*, or *horses*, while the more elaborate forms include various kinds of *screw jacks*, *ratchet jacks*, and *hydraulic jacks*.

8. Wooden Blocks.—Wooden blocks are used to a considerable extent in assembling even the heaviest apparatus, especially in the field where facilities for erecting are, as a rule, not so good as in the shop in which the apparatus is built. The blocks are usually square in cross-section often as large as 14 in. × 14 in. and of length varying from 1 to 6 feet. When blocks of this kind are to be used only once and then discarded, soft wood, such as pine, is generally selected; but if for constant service, hard wood, like oak or hickory, is to be preferred. Sometimes small wooden blocks or wedges are used for leveling apparatus on its foundation before grouting, or cementing, it in position. Hard wood should always be employed for this purpose, and the blocks should be so placed that the grain is at right angles to the pressure.

9. Iron Blocks.—Iron blocks are used more frequently in the shop than in the field, as they are more permanent and keep their dimensions better. Their greater weight is not a factor to be considered, since they are not transported great distances as in field erecting. When blocks are piled on top of one another in service, provision is sometimes made against slipping by means of slots or holes in the blocks into which T bolts or dowel-pins are inserted to lock adjacent blocks together.

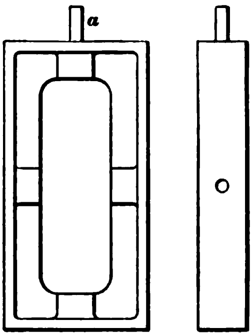


FIG. 2

The simplest and the most common forms of iron blocking are large parallels used in connection with machine tools. Large *parallels*, or *parallel blocks*, as they are often called, are usually made hollow, and are well ribbed in order to safely carry the great weight often placed upon them. *Cylindrical blocks* are also largely used.

10. Two excellent styles of parallel iron blocks are shown in Figs. 2 and 3. The form of the block shown in Fig. 2 combines considerable strength with lightness. It is planed all over so that opposite sides are parallel and adjacent sides are at right angles. When a number of such blocks are made, it is advisable to make their corresponding dimensions equal, in order that the blocks may be used in pairs. The block shown in Fig. 2 is so constructed that a number of equal blocks may be piled up

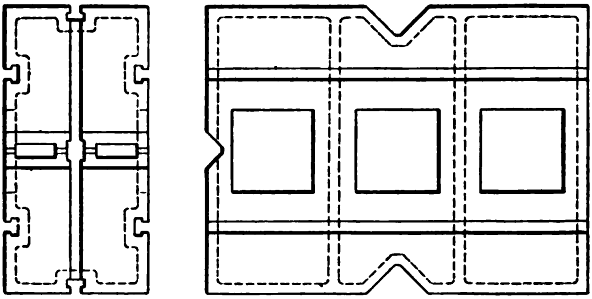


FIG. 3

to suit the requirements of the work and then form practically a single block. Holes for dowel-pins are drilled in corresponding positions in the four faces of each block. The dowel-pins are made a good fit; they prevent the blocks from slipping on each other and at the same time permit them to be readily separated. One of the dowel-pins is shown at *a*.

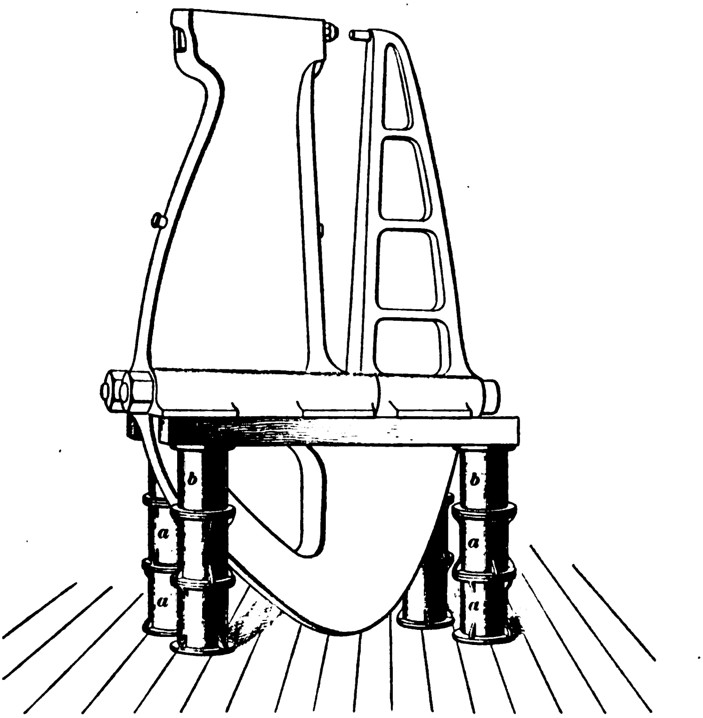


Fig. 4

11. The block shown in Fig. 3 has the general form of a box; it is finished all over and is provided with **T** slots and **V** grooves, as shown. The **V** gooves in the sides permit the block to be used with either side up for round work; the **T** slots allow the work to be fastened to the block, or the block to be secured in position by bolts. Blocks of this type may be used singly, or they may be piled up to any height that the work may require.

12. **Cylindrical iron blocking,** which is quite convenient for some classes of work, is shown, together with its application to a piece of work, in Fig. 4. The blocking resembles a short section of flanged cast-iron pipe; the sections may have the flanges strengthened by ribs, as, for instance, the sections *a*; or, the flanges may be plain, as those of the sections *b*. The flanges should be faced straight and parallel with each other, and the different sections should all have the same length.

A lighter form of pipe blocking is made of wrought iron or steel pipe that is threaded at both ends to receive flanges. The latter should be faced after they are screwed on the pipe.

13. **Trestles.**—The trestle is used as a support for large, but comparatively light, work. It may be made as is shown in Fig. 5. The legs should be cut so as to leave a shoulder *a*, and should be bolted to the beam *b* by bolts passing through the legs and the beam. When constructed in this way all the stress does not come on the bolts. When great stiffness is desired, or when the weight to be supported is rather heavy, the legs may be tied together near the bottom by boards nailed across them.

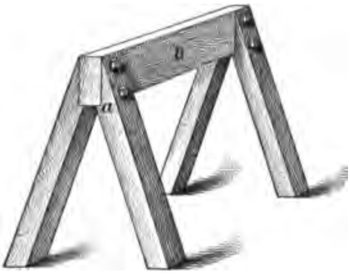


FIG. 5

JACKS

14. In addition to the parallel blocks just described, the lifting device known as a **jack** is almost indispensable in all kinds of floor work, especially in erecting. Jacks are made in a large variety of styles and sizes, from those intended for leveling up light work on the tables of machine tools to the heavy screw jacks and hydraulic jacks capable of raising or supporting 500 tons or more. They are used for a wide range of work.

15. **Simple Leveling Jack.**—The simplest form of jack consists of a circular cast-iron foot *a*, Fig. 6, which is faced at

the bottom and has a tapped hole through it. A square-headed screw *b* with a slightly rounded top, as shown, is used for raising the work. This style of a screw jack is employed principally in leveling up work on the tables of machine tools, although it will be seen later that similar jacks are sometimes made in large sizes and used in erecting.

When in use these jacks are set on the table of a machine tool in their proper positions; the work which is to be machined is then placed on them and leveled with the aid of a level or other device, the screws being turned up or down as required by means either of a wrench applied to their heads *b* or by a bar thrust through the holes *c*.

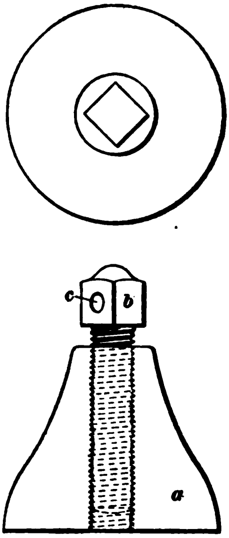


FIG. 6

16. Adjustable-Top Leveling Jack. A small jack, with an adjustable cap, which is very serviceable for machine-tool work and light assembling, is shown in Fig. 7. The body *a* is tapped to receive the adjusting screw *b*, which has a square top and holes for the rod *c*. The cap *d* is attached to the screw by a ball-and-socket joint, so as to permit the cap to accommodate itself to the angle of the work. When a solid or conical top is more suitable for the work, a second screw *e* is substituted for *b*. The foot of the body *a* is counterbored to fit the projection on

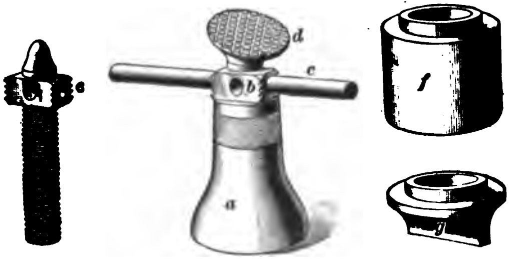


FIG. 7

the auxiliary base *f*, which may be placed under the jack when a greater height is required. Auxiliary bases of different heights may be used as needed. A special base *g* is used where a good footing for the larger base cannot be obtained.

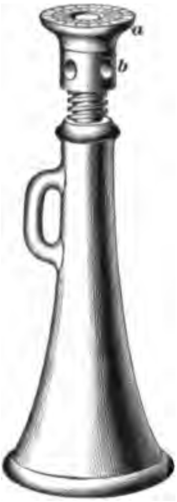


FIG. 8

17. **Screw Lifting Jack.**—When jacks are required for lifting, a different design with a greater screw travel becomes necessary, of which Fig. 8 is an illustration. The head of the screw is made with a cast-iron cap *a* that rests on a solid collar *b*; the upper end of the screw is turned down to pass through the cap and is beaded over to prevent the cap from coming off. A round bar inserted in the holes at *b* is used to turn the screw.

18. The jack shown in Fig. 8 can be used with a straight handle only where the screw can be turned through an angle of at least 90° at each setting of the bar. By bending one end of the bar through an angle of 22½°, and inserting the bent and straight ends alternately, the angle through which the screw turns for each insertion of the bar is greatly reduced. The jack can thus be operated in a comparatively narrow space; but the constant resetting of the bar consumes so much time that this method becomes objectionable where much work of this kind is to be done. Much time and hard work is saved by the use of a jack fitted with a reversible ratchet for operating the screw, as the handle of the ratchet can be turned back more easily and quickly than a bar can be removed, turned end for end, and again inserted. With a properly

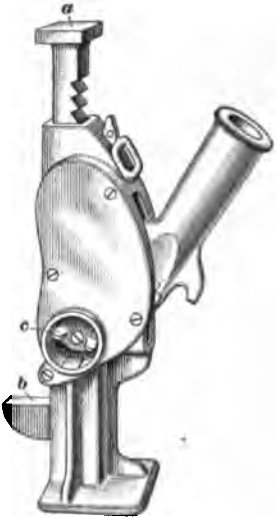


FIG. 9

formed ratchet, the jack can be operated in a very much smaller space than one operated by a detachable bar.

19. **Ratchet Lifting Jack.**—A typical form of ratchet lifting jack is shown in Fig. 9. Jacks of this class are used for various kinds of work. The load is carried by either the head *a* or the foot *b*, and is raised or lowered by means of a pawl and ratchet operated by a handle bar not shown. The load is raised or lowered on both the upward and downward stroke, the direction being controlled by the eccentric *c* at the side of the frame. These jacks have capacities as great as 20 tons.

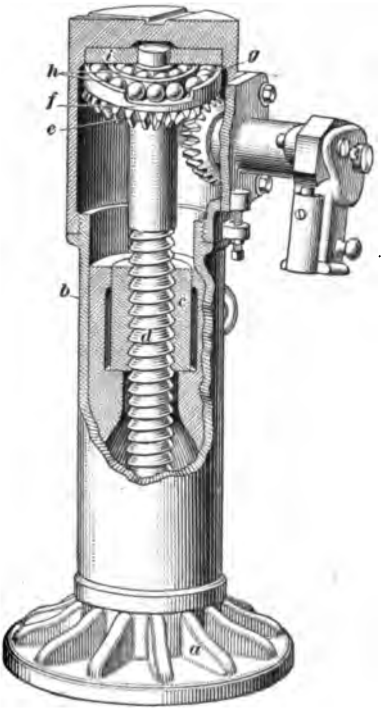
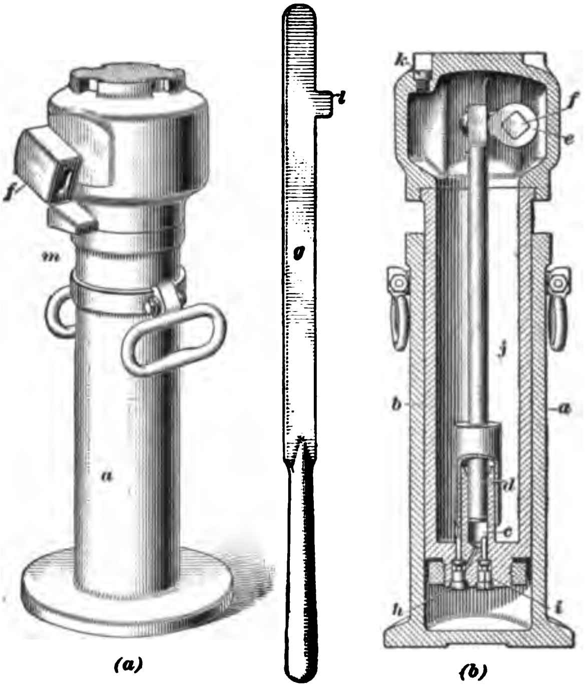


Fig. 10

20. **Geared, Ratchet, Screw Lifting Jacks.**—For capacities of from 20 to 70 tons, geared ratchet screw, or hydraulic, lifting jacks are usually employed, instead of jacks of the types heretofore described. The introduction of gearing enables greater leverages to be obtained, with consequent greater ease in raising or lowering the work. Fig. 10 shows a geared jack having a stationary steel base *a* over which is placed a sliding sleeve *b*, also of steel. The base is hollow and has in its top part a removable bronze nut *c*, in which the steel screw *d* turns. A steel bevel gear *e* is fitted to the upper end of the screw and upon it rests a hardened steel plate *f* on which are placed circular trains of hardened steel balls *g* held in position by steel rings *h*. A second hardened-steel plate *i* rests in turn upon the balls. The sliding sleeve *b*, which encloses the whole, supports the load and is carried by

this upper steel plate. The sleeve is raised and lowered by the screw which is turned by means of a reversible pawl and ratchet in a handle bar, not shown, operating through the pair of bevel gears.

21. Hydraulic Jacks.—Different kinds of hydraulic jacks are used very largely in machine shops. They are operated by pumping oil or other liquid under a piston or ram. When hydraulic jacks are subjected to cold temperatures, alcohol must be used, on account of its resistance to freezing. The lifting is done by the pressure of the fluid in the cylinder. In Fig. 11 (*a*) and (*b*) is shown a type of hydraulic jack consisting of a forged steel cylinder *a* in which is a hollow steel piston or ram *b*, free to move up or down. At the bottom of the ram and forming part of it, is a small cylinder *c*, centrally located, to



(a) (b)

FIG. 11

which is fitted a plunger or rod *d*, and this is in turn connected by the piece *e* to the part *f*, which receives the operating lever, or handle bar *g*. Two small valves, *h* and *i*, for suction and discharge, respectively, are located in the bottom of the ram, the suction valve *h* connecting the oil reservoir *j* in the ram with the small central cylinder *c*, the discharge valve *i* connecting the small cylinder *c* with the large outer cylinder which contains the ram. While the ram is in its lowest position, it is entirely filled with liquid, which is poured into it through a small screw plug *k*, shown at the top. In summer a mixture of 1 part grain alcohol and 4 parts distilled water by volume is used, while in winter the proportions used are 2 parts of alcohol to 3 parts of water. A small amount of sperm oil is usually added in either case.

22. To operate the jack, the lever, which has been placed in position with the lever lug *l*, Fig. 11, pointing downwards, is lifted, which raises the plunger, drawing oil from the reservoir through the suction valve and into the small central cylinder, the discharge valve remaining closed. On the downward stroke of the lever, the plunger is pushed down until the lug *l* comes in contact with the lug *m*, which forces the oil from the small central cylinder through the discharge valve into the bottom of the large outer cylinder, the suction valve remaining closed. As a result, the ram is raised an amount equal to the volume of oil displaced from the small central cylinder. It must be understood that this distance will not be equal to the travel of the piston, but will be as much less as the volume of the large outer cylinder is greater than the volume of the small one. To release the jack, the lever is reversed so that the lug on it projects upwards, thus allowing the plunger to be forced further down than is permitted in its regular stroke, which causes the plunger *d*, with its surrounding sleeve, to press on both valves, opening them and allowing the oil to return to the oil reservoir. Hydraulic jacks are built for capacities ranging from 10 to 500 tons. Their principal advantage over the geared type, in addition to their greater range of capacity, is that they are considerably lighter and are even easier to manipulate, though requiring a little more care for their proper maintenance. They should be used only for temporary service, as there is a tendency to leak and reduce the pressure, in spite of the best of care.

FOUNDATIONS, FLOORS, AND PITS

FOUNDATIONS

23. Temporary Foundations and Temporary Erecting.—The erecting of a machine is usually understood to include both the first erecting, in the shop where it is built, and the second erecting, on its final foundation. The two differ principally in the amount of fitting and adjusting that is requisite and the facilities for handling the heavier parts. The fitting and adjusting of all the parts are done in the shop, except in cases where some of the parts are dependent on the foundation, or must be fitted to other parts that are not available in the shop. The temporary foundation on which the work is erected in the shop is either an *erecting floor* or a *floor pit*.

24. The machine should in all cases be made as complete and as perfect as possible before it leaves the shop, because the entire equipment of the shop is available and the work can be done to better advantage, whereas any fitting necessary while setting up the machine upon its final foundation must be done with a few light tools that can easily be shipped from the shop and with such devices as the workmen may be able to contrive. The ingenuity of the erecting force is often severely tested, and the most skilful workmen frequently find it impossible to produce the grade of work that could readily be performed in the shop at a much smaller cost. It is therefore a matter of economy to be certain that every part is properly fitted and the entire machine is as complete as possible before it is shipped. The erecting on the final foundation should consist simply in putting the parts together and in making the final adjustments. This is, at best, not an easy task, especially when the machine is heavy, as the facilities for handling are almost invariably temporary makeshift devices that operate slowly.

25. Permanent Foundation and Foundation-Bolt Templet.—The permanent foundation is usually built of concrete, brick, or stone. In building, due provision must be made for the foundation bolts. Sometimes these bolts are built solidly in the foundation, while at other times they are set in pipes that hold the concrete or cement while it hardens, yet permit the bolts to be adjusted or removed entirely, if necessary. In either case the bolts must be carefully set, so that when the bed of the machine is lowered in place they will meet the bolt holes. It is usually best to make a wooden templet having the exact thickness of the bed parts, with holes in the exact location of the bolt holes in the bed through which the bolts pass. By locating such a templet carefully where the machine is to stand, the bolts can be set to the proper height and in the right places; the foundation may then be built up without any danger of a misfit.

ERECTING FLOORS

26. Foundations for Erecting Floors.—The erecting in the shop is done on a floor, the construction of which depends on the weight of the machines and the condition of the earth on which the floor is built. When the earth is dry and hard, or there is a rock bottom to build upon, the foundation of the floor may be shallow; on the other hand, when the earth is wet or unstable, a deep and solid foundation should be built up. The depth of the floor foundation depends on the weight of the heaviest parts that are liable to rest upon it.

27. Kinds of Erecting Floors.—Erecting floors are made in different ways, depending on the class of work to be done; that is, whether they are intended for permanent use for one class of work, or for a wide range of work, the needs of which cannot well be anticipated and for which changes must constantly be made. The first cost, also, often becomes an important factor in determining the style of floor to be used. To meet the various requirements, the following kinds of floor are made: *earth*, *wooden plank*, *scantling*, *wooden block*, *brick*, *concrete*, and *iron plate*.

28. Earth Floors.—Where the earth is of a firm and solid character and little money can be spent for a floor, the earth may be leveled and packed down so as to make a smooth, hard floor. Sometimes the surface is formed of a layer of iron chips from 1 to 4 inches thick that are mixed with salt or other material that will cause them to rust. When they are well packed, the surface will rust into a solid, smooth mass and then form a very good floor. Besides being cheap, the earth floor can easily be dug up to form a pit to enable any machine parts that project below the floor line to be attached. On the other hand, there is always more or less loose sand upon the surface, which is liable to get into the working parts of a machine and cause trouble.

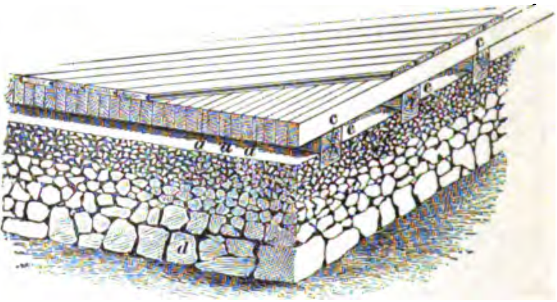


Fig. 12

29. Single-Plank Floors.—A comparatively inexpensive floor consists of 3- or 4-inch yellow pine planking, laid across joists that are placed close together and are well braced or bridged sidewise. The planks are sometimes covered with a diagonal floor of $\frac{3}{4}$- to $1\frac{1}{4}$-inch pine. The spaces between the timber should be ventilated to prevent rot. Such a floor is, however, not very rigid, and hence the heaviest grades of work require something more solid.

30. Double-Plank Floors.—A more rigid floor than the plank floor previously mentioned is illustrated in Fig. 12. The floor is built up of 2″×4″ pine scantling *a*, with a facing of from $\frac{3}{4}$- to $1\frac{1}{4}$-inch pine boards laid diagonally, as shown. The scantlings are laid on timbers *c*, which are placed in a concrete bed. These timbers are made 4 in.×4 in., 4 in.×6 in., or 6 in. ×6 in., depending on the duty for which they are intended. When the 4″×6″ timber is used, it is laid on its flat side. The thickness of the concrete depends largely on the condition of the ground. If the ground is of a firm grade, 14 inches of concrete should be sufficient for all ordinary purposes. The bed is built up by first laying a course of coarse stone, as shown at *d*, and running in some cement, then following with successive finer grades of broken stone and concrete, and finishing with a fine grade of concrete. Air spaces *e* are left between the timbers; these may be ventilated by means of openings through the walls or by holes bored through the floors. Many persons claim that this precaution should be taken with all wood floors to prevent rotting. The distance between the timbers should not be much greater than the thickness of the concrete, and it is generally thought best to limit the distance to the thickness. Excellent floors are made in this way.

31. Tar Concrete Floors.—A very good floor is made with a base of tar concrete. The ground, after leveling, is covered to a depth of about 6 inches with a layer of sand that is well rolled down. On this, 6 inches of tar concrete is placed; the concrete is composed of small broken stones covered thickly with heated tar, and, after leveling, is rolled with a heavy roller. Finally, a layer of sand mixed with considerable tar and some asphalt is applied, while hot, to a depth of about 1½ inches and after it is rolled down, is allowed to harden. When hard, a layer of 3-inch spruce planking is placed on top of the asphalt, and 1⅛-inch dressed maple flooring in strips about 4 inches wide is finally nailed crosswise to the spruce planking. The maple flooring is not tongued and grooved. No air space is left between the concrete and the flooring in this design, and the planking is laid directly upon the concrete. The tar will tend to make the foundation water-proof. The quality of lumber used and the amount of dampness in the location are important factors to be considered when deciding upon the kind of floor to use. A tar concrete floor is rather expensive, but very solid.

32. Wooden-Block Floor.—A substantial floor may be made of sawed wooden blocks, either cedar, pine, or oak, that are placed on top of a concrete bed. After tamping and leveling the ground, a layer of cinders 6 inches thick is placed on it and thoroughly rolled down with a heavy steam roller. A bed of concrete 4 inches thick is then laid on top of the cinders and leveled. The blocks may be about 6 in. × 4 in. × 4 in., and sawed from well-seasoned oak; their ends are dipped in liquid asphalt, and then laid directly on top of the concrete bed.

33. The cinders may be omitted and the concrete bed placed directly on the leveled ground, making it about 8 inches thick. The blocks are sawed to 3 in. × 12 in. × 5 in., and are placed end to end and butting together on the concrete, so that their height is 5 inches. A space of ½ inch is left between the adjacent rows, which is filled with a mortar composed of 1 part of Portland cement to 2½ parts of sand.

The advantages of a wooden-block floor are: (1) It is easy on the feet of the workmen. (2) The work is less liable to slip on it than on other kinds of floors. (3) Cleats, braces, etc. can be attached readily to the floor. (4) The expense of repairing is slight.

34. Brick and Concrete Floors.—Occasionally, a floor is made of brick laid in cement and placed on a solid concrete foundation. Sometimes hard paving bricks laid on edge are used instead of ordinary bricks, and cement is run in to fill the cracks. In some localities, a concrete base is covered with a thick layer of cement, which forms a very smooth and hard floor that is practically impervious to moisture.

An excellent and comparatively inexpensive floor consists of a layer of concrete from 8 to 12 inches thick laid directly on the ground, well tamped down, and leveled. A layer of sand about 1 inch thick is laid on the concrete, and a layer of concrete brick on the sand.

35. Cast-Iron Plate Floors.—Perhaps the best floor for large work is the cast-iron plate floor; but its great expense prevents its general use. In many shops, however, the expense is warranted, since it serves as a laying-out table and a temporary machine foundation, as well as an erecting floor.

The plates are generally made stiff enough to allow them to be supported upon masonry columns without deflection. The leveling up of the plates is thus greatly facilitated when they get out of true. Sometimes they are laid in a solid bed of concrete. The plates are then supported at every point, and when the foundation is heavy, and the plates are leveled up very carefully when they are first set, the floor is quite satisfactory for some time; but if the foundation should yield slightly, or the plates should not be set quite right at first, it is impossible to set them true without taking up the whole floor and resetting it completely. Since this is a very expensive piece of work, the masonry supports with openings between them that make all parts below the floor accessible are generally preferred.

36. The top of the floor should be planed true, and should be provided with **T** slots so that the work or portable machines may be bolted to it. The slots are usually made at right angles to each other, although sometimes they are all made parallel to one side; occasionally, when much circular work is to be machined upon the floors, the slots are run in concentric circles with radial slots crossing them at regular intervals. A board flooring is sometimes laid over the unoccupied portions of the cast-iron floor plates, to preserve them the better from damage.

FLOOR PITS

37. Use of Floor Pits.—When erecting large work provision must be made for parts that extend below the floor line, or means given to reach some of the parts from beneath the machine. For this purpose, pits are made at suitable places in the floor. Cast-iron floors are often made about the edges of these pits, which are frequently lined with plates with **T** slots running down at intervals on the inside. Pits are also used in machining very large pieces, such as flywheels, that are too large to be machined on a boring mill or in a lathe.

38. Construction of Floor Pits.—The construction of pits, like the construction of erecting floors, depends very largely on the class of work done in the shop. When a definite line of manufacture is carried on, a pit suited to the needs of the work can be built; but where work of a miscellaneous character is done, it is impossible to anticipate the needs that may arise at any time, and a pit that can easily be enlarged or changed will be most suitable.

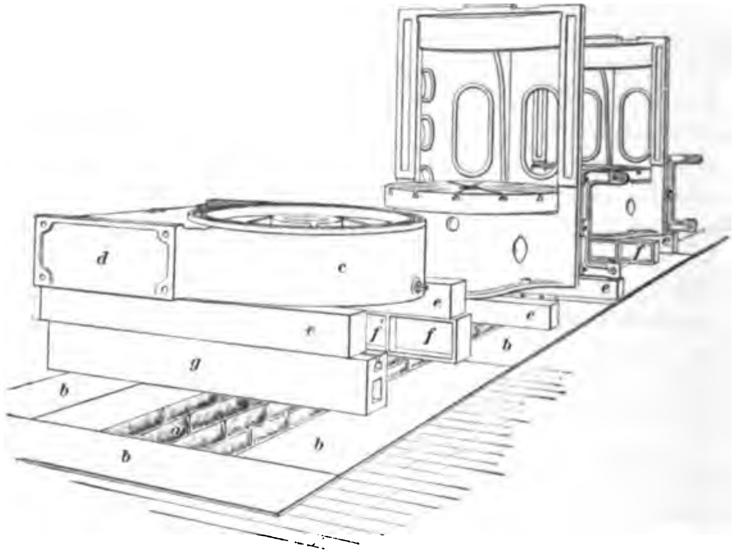


FIG. 13

39. Pit Construction for a Definite Line of Work. Fig. 13 shows a pit that is built for the purpose of erecting vertical boring mills. The sides of the pit *a* are built up of brick or stone, and iron plates *b* are placed all around the mouth of it, as shown. A convenient size of pit for this class of work is made about 4 feet deep by 4 feet wide; the length depends on the amount of work to be done.

40. The bed of the machine that is being erected is usually mounted on parallels placed across the pit. Two styles of machines are shown in Fig. 13. The machine *c* has the housings attached to the sides of the bed at *d*, and the table is rotated on a spindle that extends below the bottom of the bed. The lower end of the spindle is carried in a step bearing that is placed in a frame which is bolted to the bottom of the bed. To fit this frame properly, there should be plenty of room beneath the bed, which is therefore placed on two parallels on each side. The two machines that are shown in the rear are self-contained. The housings and the bed are one casting, and the spindle of the table does not extend below the bed. In this case, one set of parallels is sufficient to support the machine during erection.

41. Large Parallels.—Fig. 13 illustrates several styles of large parallels. The parallels *e*, which are made of cast iron, have the general form of a box that is open at the bottom and is subdivided into several compartments by webs. These webs tie the tops and sides together and greatly stiffen the parallel. The object of making the parallels hollow is to reduce their weight. It is an advantage to have all the parallels in a set of the same height, since three or more can then be used for supporting a large piece of work having a plane surface at the bottom.

The parallels *f* have an **I** section and are strengthened at regular intervals by ribs, as the one shown at *f'*. A large parallel, as *g*, is occasionally made with a rectangular hole and a **T** slot cored in it. The **T** slot permits work to be attached to the bar by means of bolts and clamps.

42. Large Masonry Pit.—Fig. 14 shows a masonry pit intended for large and heavy work. A pit about 40 feet long, 12 feet wide, and 20 feet deep is a size well adapted for heavy work. The ends *a* and the sides *b* may be built up of stone, while the bottom *c* is made of concrete and faced with cement. The top of the pit is surrounded with cast-iron plates *d* that are planed and set level. These plates are provided with **T** slots by the use of which the work may be secured to them. The ends of the pit may be built up in steps, as shown, or may be made straight, as indicated by the dotted lines *e*.

43. When not in use, the pit is covered with a plank floor, a section of which is shown in place at *f*, Fig. 14. The floor is supported upon **I** beams, as *g*, which are set in pockets *h*, in the sides of the pit. The covering floor is made up in sections so that it can easily be removed, and each section is provided with two rings *i* to facilitate the handling. The rings are attached with staples and let into the plank, so that when not in use they lie below the surface of the floor. Where the pit is not floored over, it is advisable to place a stout removable hand railing around it to prevent workmen from falling into it. These pits may be made with one or more sets of pockets *j*, to receive the **I** beams, upon which to support sections of the floor when the full depth of the pit is not required. Such a pit may be used either for erecting or for machining large parts. This form of pit is generally used when a permanent pit is desired.

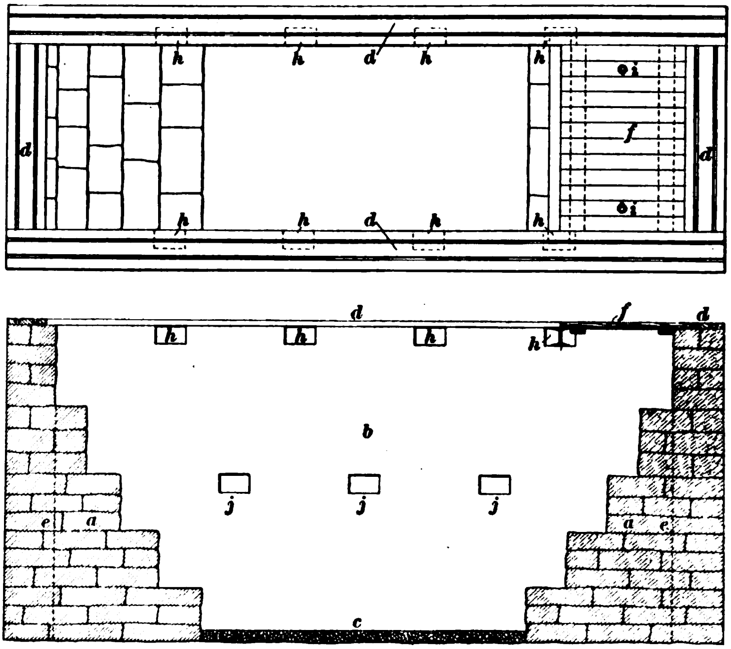


Fig. 14

44. Wooden Pit.—Another style of pit, which has the advantage of being both cheap and easily changed or enlarged, is shown in Fig. 15. The earth is simply dug away where the pit is to go, and the floor, which rests upon heavy horizontal timbers *a*, is supported about the outside of the pit by means of vertical timbers *b* standing on the blocks *c*. The floor, which covers the pit when it is not in use, is made in sections and is supported by timbers that are set into the pockets *d*, which are cut into the side timbers.

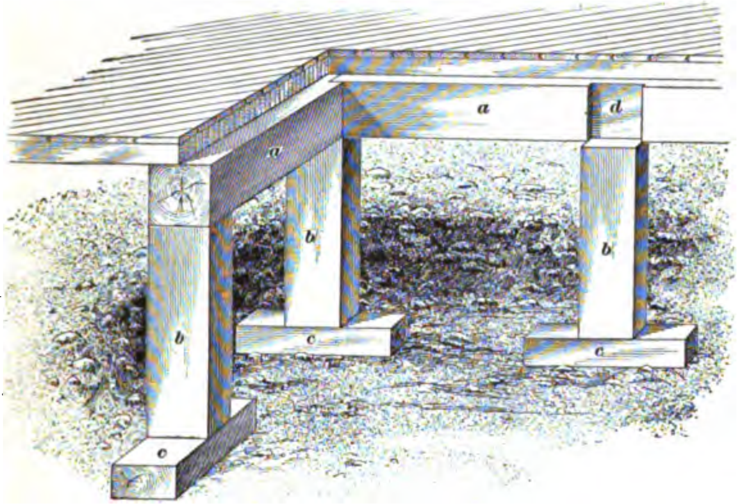


FIG. 15

HOISTS AND TRUCKS

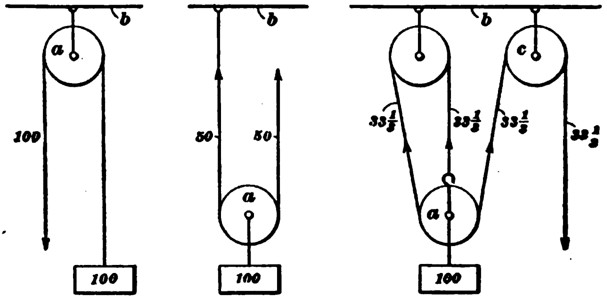
45. It frequently occurs that the heavy parts of machinery, and often the whole machine itself, must be moved, or hoisted into position. If done without proper appliances, this work involves unnecessary manual labor and becomes very expensive. Light machine parts may require no special means for hoisting, or at the most only an ordinary chain block.

The appliances used to hoist and move machinery are the *block and tackle*, the *chain* and *screw-geared blocks*, the *pneumatic* and *electric hoists*, the *derrick*, the *crane*, and the *truck*.

Whatever the type of hoisting device used, care must be taken to safeguard the operator and others. This is done by periodically testing the ropes and chains used, securing the work to the hoisting device in the correct manner, and using a device designed to lift a greater load than the one to be hoisted.

BLOCK AND TACKLE, CHAIN AND SCREW-GEARED BLOCKS

46. Principle of Block and Tackle.—The simplest form of hoisting apparatus is the block and tackle, and for some classes of work, especially in the field, it is exceedingly useful. If a sheave, or pulley, *a*, Fig. 16 (*a*), is fastened to a beam, and a rope is thrown over the sheave, a weight can be attached to one end of the rope and lifted vertically by pulling on the other end of the rope. The advantages of this device consist in changing the direction of the power exerted from an upward lift to a downward pull, since a man can employ his strength better in this way; and further, all necessity of blocking is eliminated. Practically the same pull is required as the weight to be lifted, if friction is neglected, and for every unit of distance the weight is lifted upwards on one side of the sheave, the rope travels downwards an equal distance on the other side.



(*a*) (*b*) Fig. 16 (*c*)

If the weight be taken as 100 pounds and the distance from the floor to the beam as 10 feet, then when the weight is on the floor the total length of rope is 20 feet; but when the weight has been lifted to the beam a distance of 10 feet, 10 feet of the rope have been hauled in, and a pull of 100 pounds has been exerted during the whole time of hauling.

47. In Fig. 16 (*b*) one end of the rope is shown attached to the beam *b*. If a man stands on the beam pulling upwards on the other end of the rope with a 100-pound weight attached to the sheave *a*, then only 50 pounds pull need be exerted by the man to lift the weight, the other 50 pounds being held by the beam. This point will be more quickly understood if in place of one end of the rope being tied to the beam, it is held by a second man, thus dividing the weight equally, each man holding 50 pounds. For every unit of distance the weight is lifted upwards, twice as much rope, as in the first case, must be hauled in. When the weight is on the floor, the total length of rope is 20 feet; but when the weight has been lifted to the beam a distance of 10 feet, all of the rope, or 20 feet has been hauled in.

48. In Fig. 16 (*c*), the same weight is shown being lifted by the aid of three sheaves and 40 feet of rope. In this case, for every unit of distance the weight is lifted, three times as much rope must be hauled in as in the case illustrated in (*a*). The total weight, 100 pounds, is supported by three ropes, each rope supporting one-third of this weight or 33⅓ pounds. The pulley *c* is used so that the pull may be exerted in a downward direction. When the weight is on the floor, the total length of rope is 40 feet; but when the weight has been lifted to the beam, 30 feet of rope have been hauled in.

Rule.—*In every block and tackle, the pull required to hold any weight is equal to the weight divided by the number of ropes supporting the weight.*

When applying the rule, care must be taken not to count a free end used to change the direction of pull. For example, the left-hand rope in Fig. 16 (*a*) and the right-hand rope in (*c*) are free and should not be counted; while in (*b*) the right-hand rope is supporting the load and should be included.

49. Example of Block and Tackle.—One form of block and tackle is shown in Fig. 17. According to the method followed in practice, the sheaves, instead of being separated, as shown in Fig. 16, are placed in one block. The block and tackle, as compared with the chain block, to be described later, are lighter and can be used to lift weights to greater heights since ropes are made in greater lengths than chains. For hoisting, the block hook *a* should be attached to some fixed support above and the tackle hook *b* should be made fast to the work. In this case a given amount of pull on the free rope *c* will cause an equal pull on the other ropes *d*, *e*, and *f*, so that, neglecting friction, a given pull on *c* can lift three times the load on the hook *b*.

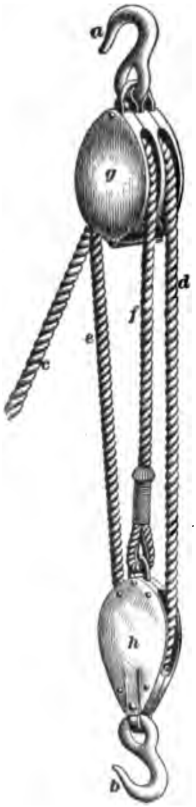


FIG. 17

The block and tackle is particularly useful in drawing to one side a weight suspended from a heavier tackle or for moving machinery supported on rollers. Judgment should be exercised in using the block and tackle to the best advantage when dragging weights horizontally; for example, if the block and tackle in Fig. 17 be used to draw a piece of machinery along the floor of a shop, the single-sheave end *h* should be attached to some stationary object, as a girder, while the double-sheave end *g* should be attached to the piece of machinery to be moved. This has the advantage of giving four ropes which pull on the greater block *g*, whereas, reversing the block and tackle reduces the number of the ropes that pull on the block *h* to three, and therefore increases the pull required on the rope *c*.

50. Differential Chain Block. Although, as already stated, the block and tackle is lighter and with it loads can be lifted through a greater distance than with the differential chain block, the latter can lift far heavier loads and is much more durable in construction. The differential chain block consists of an endless chain *a*, Fig. 18, a differential chain wheel *b*, a single-grooved pulley *c*, and the hooks *d* and *e*. The differential wheel has two chain grooves of unequal diameters.

The grooves are notched, forming two chain sprockets. As the chain is drawn over the pulley so that the latter revolves, a greater length of chain per revolution will travel over the groove with the larger diameter than over the one with the small diameter. Therefore, when the side of the loose loop *a*, which is on the large diameter, is drawn down, it will shorten the distance between the two pulleys and lengthen the loose loop. By drawing down on the other side of the chain that runs over the small diameter, the distance between the pulleys is increased. A weight hanging on the hook *e* will be raised or lowered, depending on which side of the loop is pulled.

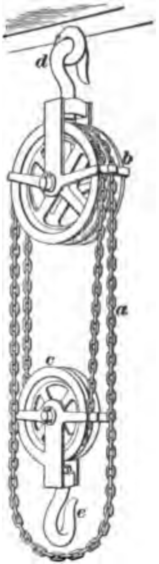


FIG. 18

51. One great advantage of chain hoists lies in the fact that they may be stopped at any point; that is, the load will remain stationary, without fastening the chain in any way, until set in motion again by the operator. With a tackle the free end of the line must be fastened to some stationary object in order to hold the load, which is often a drawback to the use of the tackle. To offset this, is the fact that, with long usage, the iron in the chain links becomes crystallized, and is liable to break suddenly even under a moderate load. The effects of crystallization can, however, be remedied to a large extent by a thorough annealing of the chain. The chain should be removed from the blocks, coiled, and a wood or charcoal fire built around it. No blast should be applied to the fire, which should be built in the open air. After the chain has been heated to a cherry red, it should be placed in an iron box, the bottom of which has been covered with powdered charcoal. The chain should be covered with the same substance, the box closed, and the chain allowed to remain until cold. It may then be rove through the blocks again, and will be nearly as good as when new.

52. Screw-Geared Block.—A still more efficient type than the differential chain block is the screw-geared block made in a variety of forms, one of which is shown in Fig. 19 (*a*) and (*b*). It consists of a central worm *a*, driven by a chain wheel *b* over which is thrown a hand-operated chain *c*. Meshing with this worm is a gear *d* having fastened on each side of it small chain wheels *e* over which the load chain *f* is thrown. To the ends of this chain is attached a hook *g* for lifting the load. The worm and gear run in a bath of oil. The chain wheels *e* are supplied with safety guides to prevent the load chain from slipping. This device is light in weight, requires little headroom, and is well adapted for setting machinery.

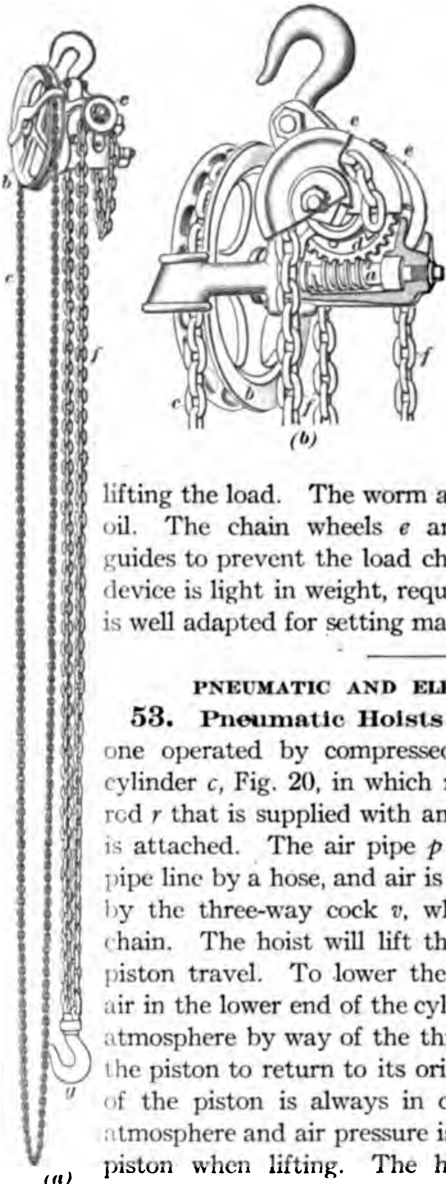


Fig. 19

PNEUMATIC AND ELECTRIC HOISTS

53. Pneumatic Hoists.—A pneumatic hoist is one operated by compressed air. It consists of a cylinder *c*, Fig. 20, in which moves a piston having a rod *r* that is supplied with an eye *e* to which the load is attached. The air pipe *p* is connected to the air-pipe line by a hose, and air is admitted to the cylinder by the three-way cock *v*, which is operated by the chain. The hoist will lift the load the length of its piston travel. To lower the piston, the compressed air in the lower end of the cylinder is exhausted to the atmosphere by way of the three-way cock, permitting the piston to return to its original position. The top of the piston is always in communication with the atmosphere and air pressure is on the lower side of the piston when lifting. The hoist described is single acting. It is shown mounted on a runway.

54. Electric Hoists.—Like the pneumatic hoists, there are many types of electric hoists available for different classes of work. They embody the same general principles, differing only in details of construction. One type of hoist is shown in Fig. 21. The hook *a*, which is connected to the part to be hoisted, is raised and lowered by electric power while the hoist and work are moved along the jib way *b* by pushing or pulling on the work or hook. When traversing, the trolley pulleys *c* roll on the track *d*. The power for hoisting and lowering the work is supplied to the motor *e* by the electric wires *f* and the wheels *g*. The hook *a* is connected to the hoisting drum *h* by the rope *i* which runs over the pulley *j*. The hoisting drum is driven from the pinion of the motor by a train of gearing.

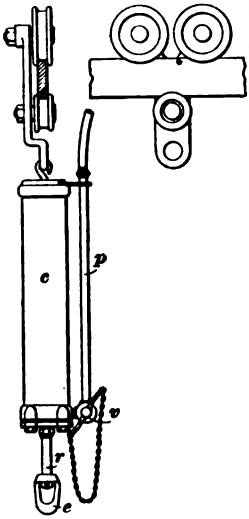


FIG. 20

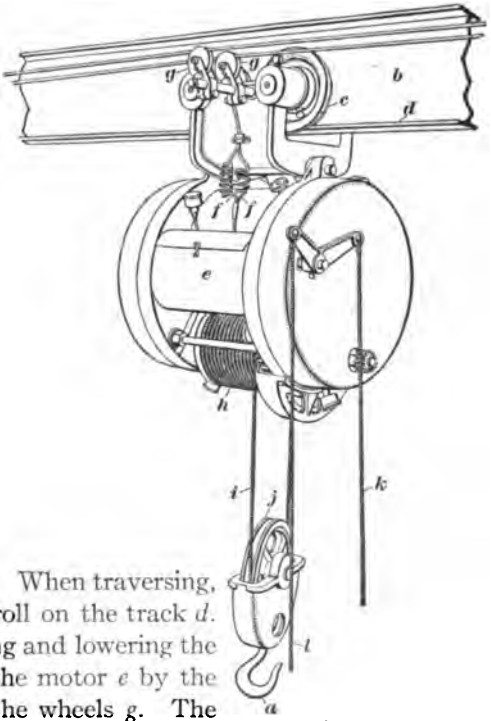


FIG. 21

55. When the hoist is stationary, pulling the rope *k*, Fig. 21, downwards operates the controlling mechanism, causing the electricity to flow through the motor in the direction needed to hoist the work. Pulling the rope *l* downwards then stops the hoisting, and pulling it still farther down reverses the direction of flow of the current through the motor and consequently lowers the work. Pulling the rope *k* downwards would, in this case, stop the motor, and hence the descent of the work. A brake is enclosed in the casing which, when the ropes are adjusted to the stopping positions, operates to prevent the work from descending. Some types of hoists are provided with motors which move them along the track.

Electric hoists are used for practically the same classes of service as are the pneumatic hoists; and, while at times there is little to choose between them, at other times, one type may have an advantage over the other. They are built for both stationary and traveling service.

CRANES AND TRUCKS

56. Portable, Hand-Operated Cranes.—A portable, hand-operated crane, Fig. 22, is very convenient for transporting loads up to approximately 3 tons. In the type illustrated, when the crane is stationary and the load is being raised or lowered, the handle *a*, which is connected to the crank-shaped axle of the front wheels, is thrown up. This operation lowers the body *b* of the crane on the front wheels, which then support the weight. A small **V**-shaped foot *c* is provided on both sides of the base which while clearing the floor level, is long enough to prevent the load *d* from tilting sidewise. The hoisting is done by turning the crank *e*. A ratchet wheel *f* and pawl *g* serve to hold the load at the height to which it has been raised. When the load must be lowered rapidly, the pawl may be turned over so that its back will rest on the ratchet wheel.

57. Jib Cranes.—Limited areas, and often one or two machines, are served by jib cranes, one form of which is shown in Fig. 23. Heavy jib cranes, capable of lifting 30 tons, are in use in some shops, although for heavy work the traveling crane is generally preferable. Jib cranes may be equipped with hoists that are operated either pneumatically, hydraulically, or electrically, or with a chain or screw-geared block.

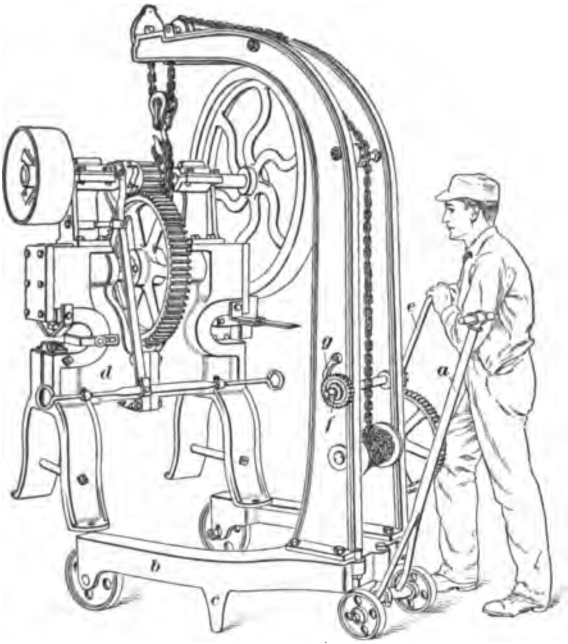


FIG. 22

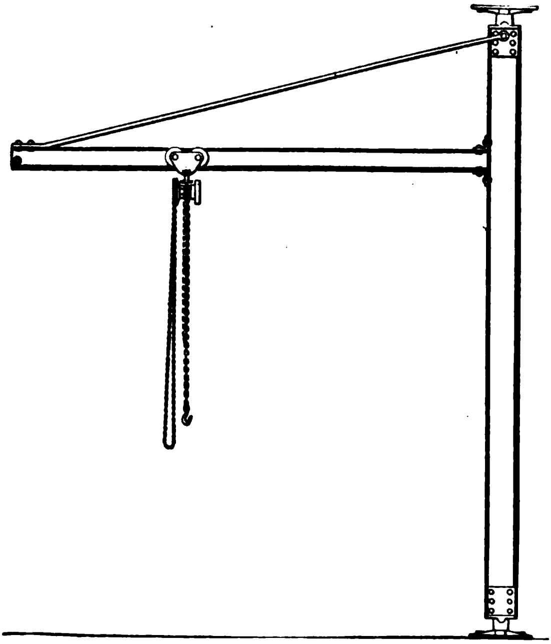


FIG. 23

58. Trolley Cranes.—The traveling hoist furnishes an extremely useful and convenient method of handling light and medium-heavy work, and it is especially adapted to shops having low ceilings in which the traveling crane cannot be used. The runway or track used in this system of shop

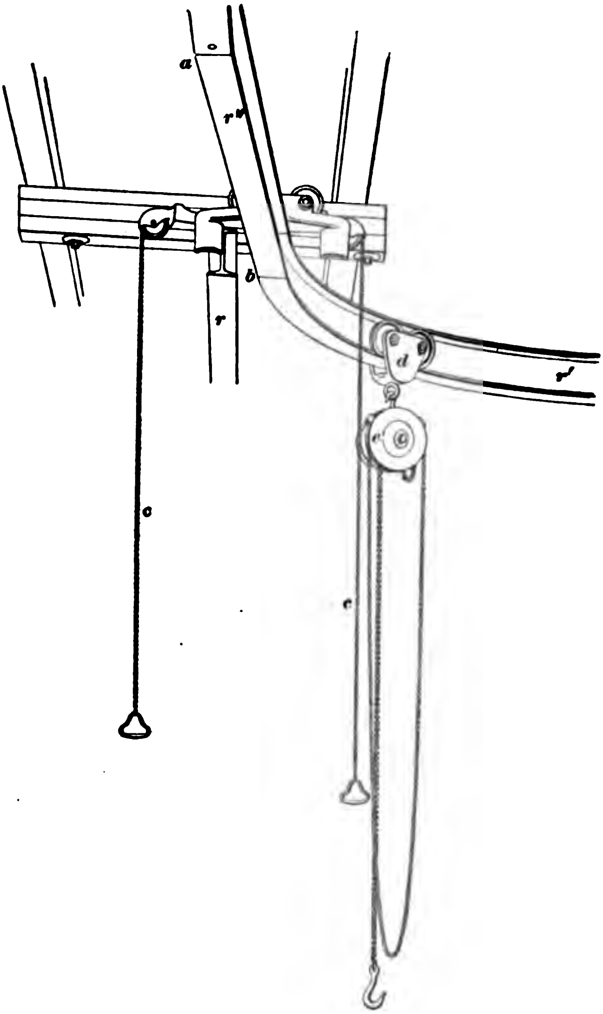


FIG. 24

transportation consists of I beams suspended from overhead, as shown in Fig. 24.

The illustration shows how the traveler *d* may be switched from the main track *r* to a side track *r'*. A section *r''* of the main track is hinged at *a*, and its free end can be swung in line with the main track or side track by pulling one of the chains *c*. The hoist *e* is attached to the traveler.

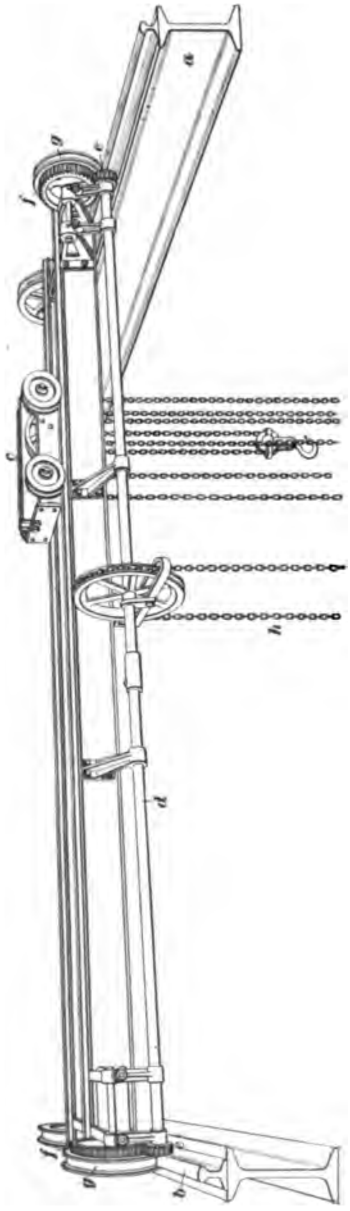


FIG. 25

59. Kinds of Traveling Cranes.—The traveling crane furnishes the most modern and convenient means of shop transportation. Cranes of this kind are operated either by hand, by power-driven shafting, or by electric motors. The traveling crane is a bridge-like structure, that spans the floor and is supported on steel rails placed on suitable supports.

60. Hand-Operated Traveling Cranes.—Fig. 25 illustrates a hand-operated traveling crane, having a capacity of from 2 to 6 tons and built for spans of 30 feet or more. The span portion of the crane is called the bridge and the part containing the hoist, the trolley. I beams *a* carry the rails *b* on which

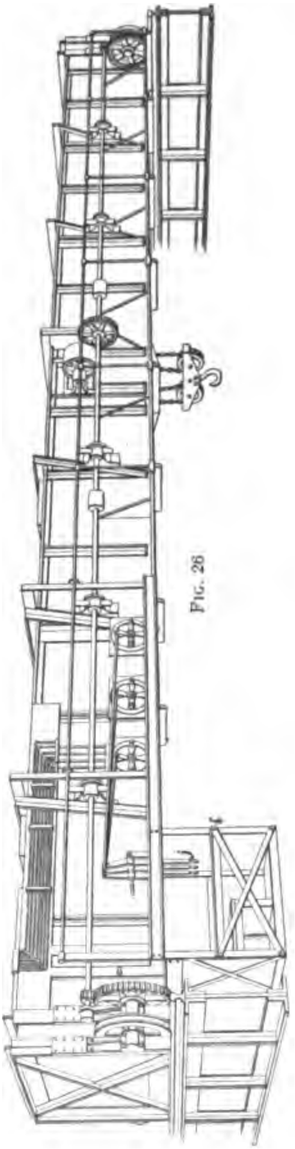


Fig. 26

the crane runs. In the case of heavy cranes, these **I** beams are replaced by built-up girders. These runways are placed as high up in the building as possible in order to get as much room under the crane as can be had. The runway extends the whole length of the floor or building and a trolley *c* running on rails can travel from one end of the bridge to the other, and hence can be brought over any point on the floor. Hand cranes like the one illustrated are operated from the floor in the following manner: A shaft *d* has a pinion *e* on each end that meshes with the gears *f*, which are keyed to the same shafts to which the wheels *g* are fastened. The shaft *d* is rotated by pulling the chain *h*, and the crane is thus made to traverse the building lengthwise. A similar mechanism runs the trolley *c* from one end of the bridge to the other. The hoisting is done from the floor.

61. Electric Traveling Cranes.—The electrically driven traveling crane may be driven by a single motor and the separate parts may be run by trains of gearing from it; but more generally it has a separate motor for each movement. Many such cranes intended for heavy work have an auxiliary hoist, to allow light work to be handled much quicker than can be done with the main hoist. The auxiliary hoist is mounted on the trolley.

The current for operating these cranes is taken from wires

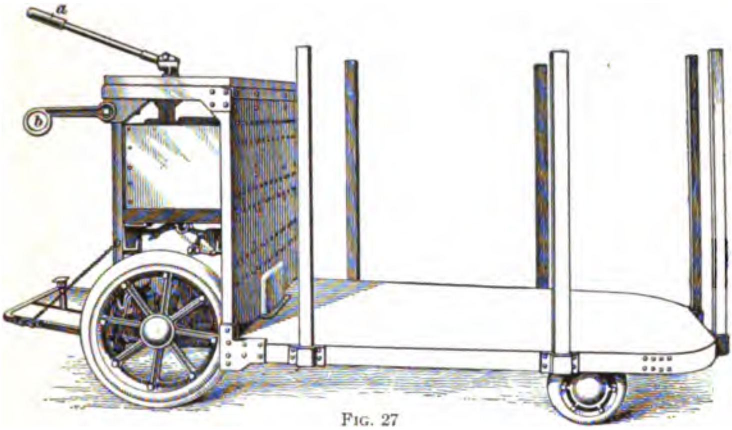


Fig. 27

located along the sides of the building close to the rails. The operator is carried in a cage *i*, Fig. 26, suspended below and to one side of the bridge, where he controls the various movements by means of levers, switches, or other devices shown at *j*.

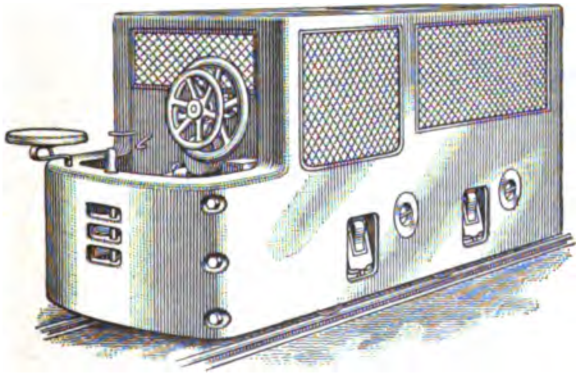


Fig. 28

Electric traveling cranes are built for spans as great as 75 feet. For heavy work, they are both economical and quick in operation.

62. Trucks.—*Hand trucks* are the most common conveyance for small loads. They are also the most inefficient vehicle used, in their method of employing human labor. Electric- and gasoline-operated trucks are consequently gradually replacing them.

Electric trucks may be either self-contained and operated by storage batteries mounted directly on them, as in Fig. 27, or they may be driven from a central station through the medium of an overhead trolley. The former are employed both for indoor and outdoor service; the latter largely for outdoor use. The truck shown in Fig. 27 is steered by the lever *a*, and the speed of the truck is controlled by the lever *b*. *Gasoline-operated trucks*, Fig. 28, are, like the battery-operated trucks, self-contained; but unlike them, they are largely confined to fixed routes, in which respect they resemble the trolley-driven electric trucks. They are used principally for outdoor transportation.

DERRICKS

63. A common form of **derrick** is shown in Fig. 29. It consists of a mast *a*, the lower end of which is set into a base *b* that is secured to the timber framing *c* shown in the illustration. The upper end of the mast carries the derrick head *d*, to which the guy ropes *e*, *f*, *g*, and *h* are fastened. These guy ropes are fastened to stakes driven into the ground, or to any other immovable objects that are conveniently located, and serve to steady the mast. The mast has pivots at both ends that enter sockets in the base and in the derrick head, and allow the mast to be rotated. The boom *i* is hinged to the mast at *k*, and can be raised or lowered by the tackle *l*. The tackle *m* is used for hoisting weights.

64. When the upper end of the mast and boom are tied together by a *jib*, or horizontal member, the whole device is called a *crane*. A crane is usually fitted with a traveling carriage on the jib.

65. Erecting Gin Pole.—A **gin pole** is a vertical pole used for hoisting. When erecting a tall derrick, a gin pole is first put up to assist in raising the mast; but if the derrick is low, its boom may be used for this purpose. Before erecting the gin pole, a pulley is secured to its top and a rope passed over it. One method of erecting the gin pole is to slip an iron bar *a* through the hole in the lower end and secure it to suitable stakes *c*, as shown in Fig. 30. The free end of the gin pole

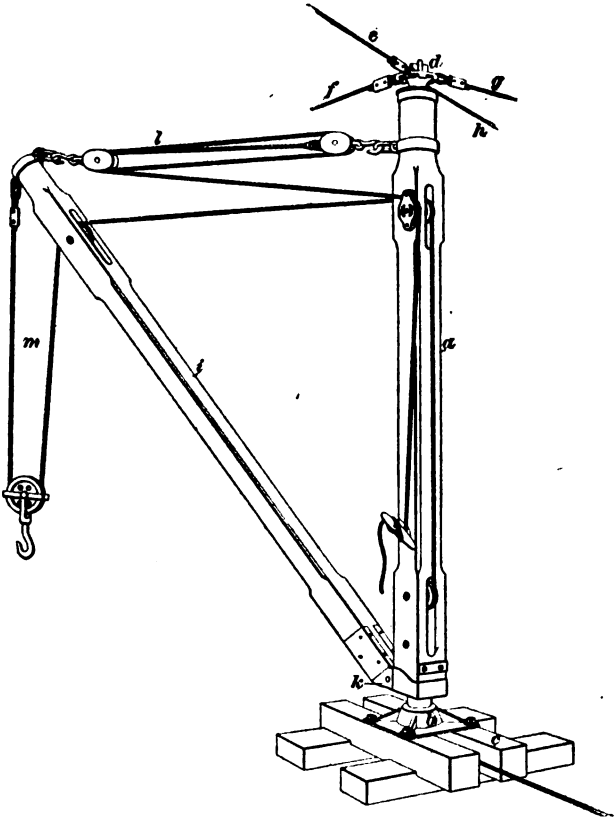


Fig. 29

is then lifted from the ground and placed on the **X**-shaped brace *e*. The guys *f*, *g*, *h*, and *i* are then attached to the upper end *d* and are laid out on the ground ready for use. The men now raise the gin pole *b* by means of pike poles and advance the support *e* toward the lower end. When the free end has been raised some distance from the ground, the ropes *f* and *i* may be pulled, thus helping to raise the gin pole to a vertical position; meanwhile, the men who attend to the guys *g* and *h* must see that the gin pole does not shift from the desired position. Usually only one man is required for each end of the guys *g* and *h*, since he can wind the rope about a stake, and then easily prevent the gin pole from moving too far. When the gin pole has been raised to the vertical position, the guys *f*, *g*, *h*, and *i* are secured to the anchor stakes as shown in Fig. 31. Guys used for a gin pole are generally made of manila or hemp rope.

66. Erecting Mast of Derrick.—After the gin pole has been raised into an upright position and the guys have been fastened, it may be used to lift the mast, as is shown in Fig. 31, in which *a* represents the gin pole, the lower end of which is lashed to the stakes *c*. The derrick head *g* should be placed in position, the guys attached and the hoisting rope passed over the head sheave before the mast is raised. The base for the derrick having been located and fastened to the timbers *b*, the mast *d* is hoisted into position by means of a rope fastened a little above its center and passed over the pulley *e* on the end of the gin pole. The other end of this rope *f* may be handled by hand if the mast is not too heavy, or by a suitably located winch, or crab, if the mast is of considerable weight. The lower end of the mast is now lowered into the base, after which the guys attached to the head *g* are tightened and

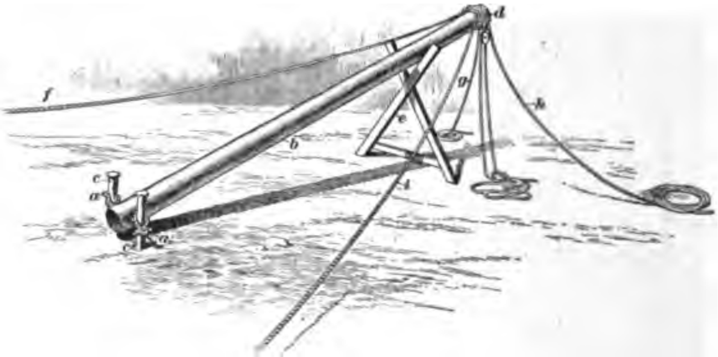


FIG. 30

fastened in position. The permanent guys for the mast are usually made of wire rope.

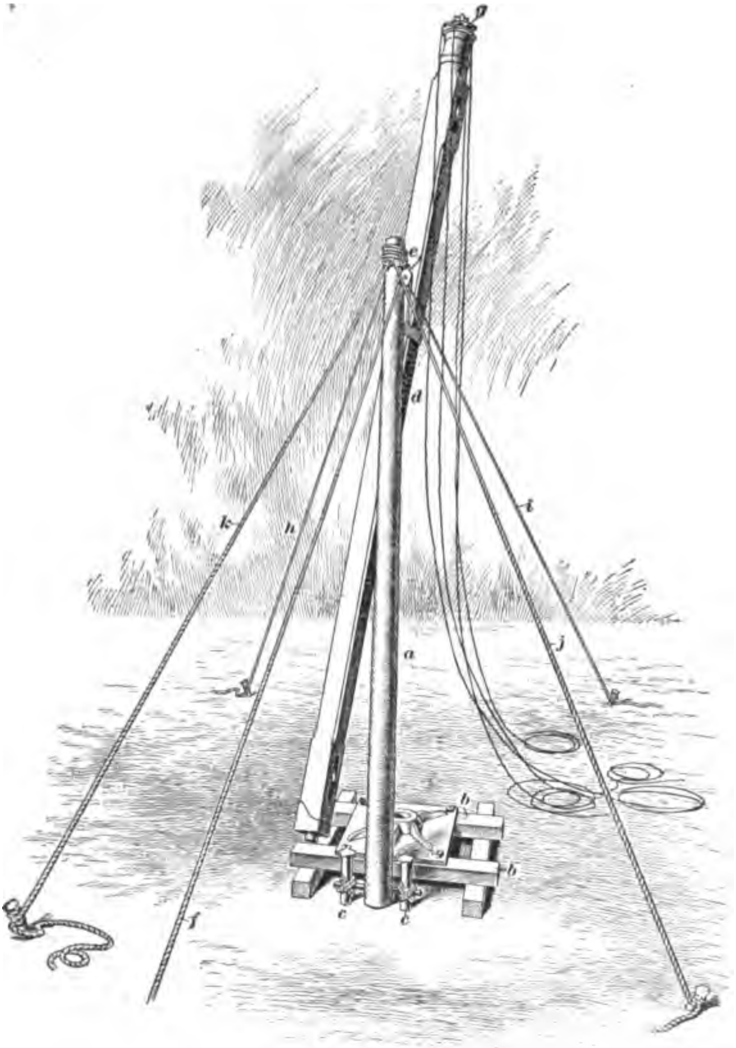


FIG. 31

67. Placing Boom of Derrick.—After the mast has been properly guyed and the gin pole has been taken down, the hoisting rope is hitched around the boom, and it is raised until the bottom end can be swung into the knee *k*, Fig. 29, where it is secured by a pin. The ropes are then all reeved through their proper pulleys and the derrick is ready for work.

Large derricks are generally erected by the aid of a separate gin pole, as just described. In the case of a very large derrick it is sometimes necessary to erect a gin pole of a height such that the men can handle it, and use it for setting the boom on end, which is then used as a gin pole for lifting the mast. Two separate sticks of timber are sometimes used as gin poles, a short one, less than one-half the height of the mast, being employed to set a gin pole about two-thirds the height of the mast; this second gin pole is then employed for setting both the mast and the boom. Derricks so large as to require two gin poles for their erection are rarely used except on permanent work.

68. **Erecting Small Derrick.**—With small derricks, a gin pole is seldom used for raising the mast, as the boom is generally light enough to be erected as a gin pole, and is then employed for raising the mast. After the mast has been raised and securely guyed, the mast itself is used for swinging into position the boom, which up to this time has served as a gin pole.

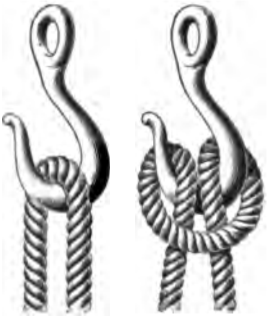
69. **Dismantling Derrick.**—When the work has been finished and it becomes necessary to dismantle the derrick, the boom is hoisted up to the mast, and is detached from the knee. Stakes are then driven into the ground and the lower end of the boom is lashed to them; the boom is then used as a gin pole for lowering the mast. The boom itself is lowered afterwards by paying out two of its temporary guys until it can be caught on a support similar to that shown at *e*, Fig. 30.

If the boom is too large to be handled in this way, a smaller gin pole is erected alongside to take the large one down, and then lowered by the guys and **X** brace.

ROPES

70. Materials Used for Ropes.—Until comparatively recent years, all ropes were made of vegetable fiber teased out and spun into suitable form either by hand or machinery; but since the introduction of iron, and particularly of mild steel, into the rope-manufacturing industry, steel rope is rapidly superseding all other rope for certain classes of work. For many purposes, however, fiber ropes are still used and can never be replaced by steel ones; they are made, for the most part, either of hemp, manila, or coir, which is cocoanut-husk fiber. First, the fibers are spun into yarns, then the yarns into strands, and, finally, the strands into rope.

71. Slings.—Loops of rope or chain used for attaching weights to the hook of a tackle or for fastening a tackle block to some support, are known as **slings**. That a sling may best serve its purpose, one of several methods of fastening it to the block must be chosen, the choice depending to some extent on the weight of the load to be lifted. For instance, the resistance of the sling is least if used single, as shown in Fig. 32 (*a*); but its greatest possible strength may be obtained by use of a half-hitch; that is, by looping it over the hook as shown in Fig. 32 (*b*), thus increasing the surface of the sling in contact with the hook of the tackle block. The sling may be applied to the piece of work to be moved either singly, as in Fig. 32 (*a*), or doubled, as in (*b*), the latter method being preferable owing to the absence of any danger from slipping of the sling. If the sling is fastened by doubling over, a noose is formed and the sling is thus tightened on the work when the free end is pulled.



(*a*) FIG. 32 (*b*)

72. Lashings.—Where headroom is limited, the tackle may be attached to the work by means of a lashing, that is, a piece of rope sufficiently long to admit of its being passed several times around the piece to be moved. Work is fastened to the tackle by first bringing the back of the hook of the tackle block in contact with the piece to be hoisted, as shown in Fig. 33, and then passing several turns of the line around the work and over the hook, the ends of the line being fastened by a knot. A small rope may be used for lashing, the necessary strength being obtained by increasing the number of turns.

73. Inspection of Ropes, Slings, and Lashings. From repeated use and occasional abuse, the strength of ropes, slings, and lashings will be impaired; to prevent any accident that might occur from this loss of strength, it is necessary to know how to detect a weakened rope. The outside must first be inspected carefully, running over the lines from end to end, and noting if any of the strands, or yarns composing the strands, are damaged. If nothing wrong is discovered about the outside of the rope, the inside should be inspected, as a rope will often be perfectly sound on the outside, but utterly bad inside. The inside may be inspected by taking the rope in both hands and untwisting it sufficiently to expose the inner surfaces that have been chafing against one another. Then, if the life or utility of the line has been impaired by long use, a considerable number of broken fibers will be found; if in a bad state, they may have been reduced to powder. If broken fibers are discovered, the use of the rope should be confined to loads not heavier than half the load it formerly could stand; if a considerable quantity of powder is found, the line should be condemned at once as unfit for use.

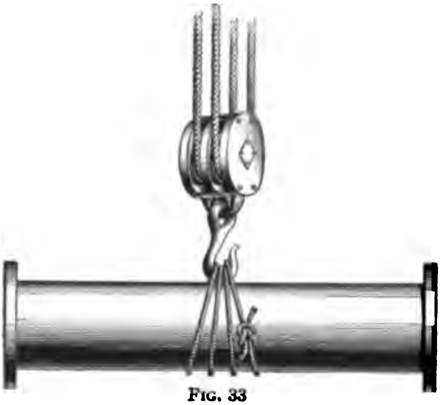


FIG. 33

Slings and lashings, as a general rule, are ruined by external chafing received when moving rough castings, etc., and hence their safety can be determined from their external appearance. Ropes or lines, on the other hand, when used for tackle blocks, receive the greatest wear on the inside, owing to the chafing and grinding of the strands when passing over small pulleys under heavy strains.

74. Splicing.—The operation of so joining two pieces of rope as to obtain one continuous piece with no appreciable increase of diameter at the splice, is known as splicing. The principal splices are the *short splice*, the *long splice*, and the *eye splice*.

The principle of all splicing consists of joining, or *marrying*, the strands, thinning them out and tapering them so that the diameter at the splice is the same or only slightly greater than that of the rope itself. In the long splice, no increase in diameter is allowed. The methods of splicing described and illustrated in this Section apply only to three-strand fiber ropes.

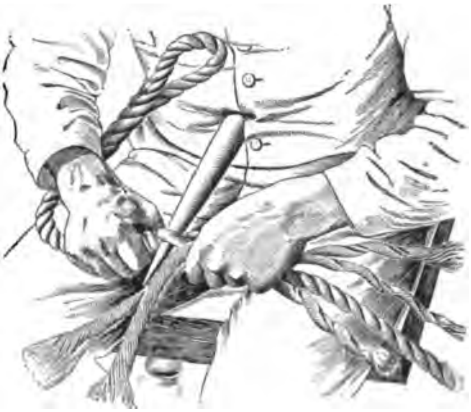


FIG. 34

75. Splicing Tools.—The only tools necessary for making a splice are a **marlinspike,** shown in Fig. 34, and a knife. The former is made of either iron or hard wood, is from 12 to 14 inches long, and about 1 inch in diameter at the thick end, the other end being sharpened to a blunt point about as shown in the figure. When splicing, the point of the marlinspike is pushed through the rope, between the strands that are to be separated, the thick end is placed against the body of the operator, and, using both hands, the rope is untwisted so as to render the work of opening the strands comparatively easy. The rope is held by the left hand, the joint being made by manipulating the end of the rope held in the right hand.

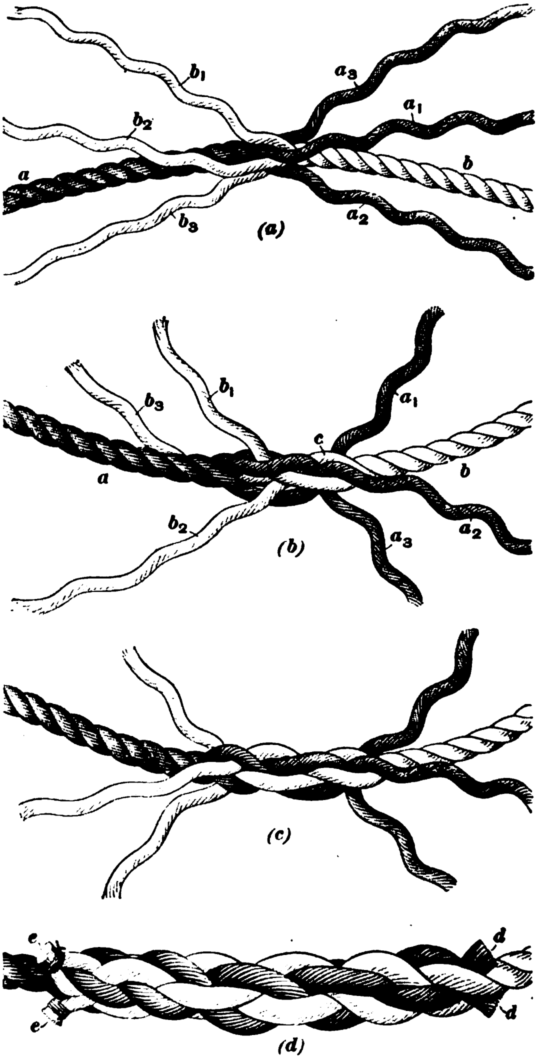


FIG. 35

76. Making Short Splice.—In making a short splice, the strands at the end of each rope are first unlaid, that is, the strands are untwisted—a distance, for a 1-inch rope, of about 16 inches. Ropes of other diameters are unlaid a proportionate distance. A few inches too much unlay is better than too little, as the ends must be cut off anyway. The ends of the ropes *a* and *b*, Fig. 35 (*a*), are now married—that is, the strands a_1, a_2, and a_3 of the one rope are placed between the strands b_1, b_2, and b_3 of the other rope. The strands b_1, b_2, and b_3, and the rope *a* are now held in the left hand; if the ropes are too large to be held in this way they may be fastened together with twine. One of the strands, say a_1, is then pushed under the second strand in front of it, shown at *c*, Fig. 35 (*b*), an opening having previously been made either with the thumb or a marlinspike as illustrated in Fig. 34. This operation is known as *tucking*. Similarly, the strands a_2 and a_3 are tucked under the second strand in front of each. The splice now appears as shown in (*b*). The strands b_1, b_2, and b_3 are now tucked under the second strand in front of each, and the splice appears as shown in (*c*). To secure strength, more tucks are made, and, after subjecting the rope to a good stout pull, the ends of the strands are either cut off as shown at *d* in (*d*) or are whipped as shown at *e*. To whip the strands, one-half of each strand is wrapped, or bound, with twine to one-half of the adjoining strand. Whipping prevents the strands from creeping through when the splice is taxed to the full capacity of the rope.

77. Making Long Splice.—In the short splice, the diameter at the joint is greater than that of the rope, hence it is not a suitable splice where the rope is to be used in tackles and pulley blocks, or in other places that will admit nothing larger than the rope itself. In such cases the long splice is used. When properly made, the untrained eye can hardly distinguish this splice from the rest of the rope. To make the long splice, the ends are unlaid as before, but about three times as far, and married as shown in Fig. 35 (*a*). The strands a_2 and b_2, Fig. 35 (*a*), are then laid together as shown at *f*, Fig. 36. The strand b_1, Fig. 35 (*a*), is now unlaid gradually and in the groove thus made the strand a_1 is laid. Care should be taken to give all the strands the proper twist, so that they will fall gracefully into the grooves. The original twist in the strands is thus retained for subsequent operations. The strands a_1 and b_1 are laid together at *g*, Fig. 36, as was done at *f*. The strand a_3, Fig. 35 (*a*), is next unlaid gradually and in the groove thus made the strand b_3 is laid. These strands are now laid together at *h*, Fig. 36, as was done at *f*, and the ends of all the strands are cut off to a length about as shown in the figure.

78. The strands a_3 and b_3, Fig. 36, are now relieved of about one-third of their yarns—that is, the portions a'_3 and b'_3 are cut off close to the rope. With the remaining parts of a_3 and b_3, an *overhand knot* is cast, like that shown at *g*, Fig. 36. An opening having been made with the thumb or marlinspike as shown in Fig. 34; the strand b_3 is tucked under the strand immediately in front of it, *i*, and pulled taut as shown in Fig. 37 (*a*). Similarly, the strand a_3 is tucked under the strand immediately in front of it and pulled taut.

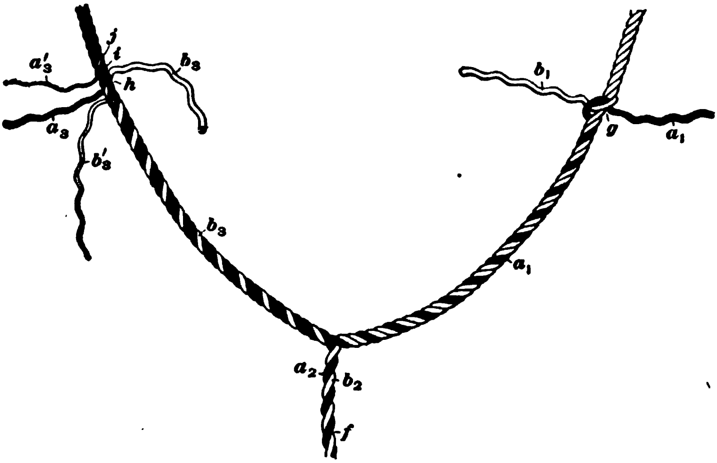


FIG. 36

The strands a_3 and b_3 are now relieved of about one-third of the yarns remaining, the parts a_3'' and b_3'', Fig. 37 (*b*), being removed; and, an opening having been made either with the thumb or marlinspike, the strand b_3 is tucked under the second strand in front of it, *j*, Fig. 36, and pulled taut. Similarly, the strand a_3 is tucked under the second strand in front of it and pulled taut. Further tucks may be taken, if desired. The splice is next finished at *f* and *g*, Fig. 36, in the same manner as at *h*. The rope is now given a good stout pull and the ends of the strands are cut off. The finished splice appears as shown in Fig. 38.

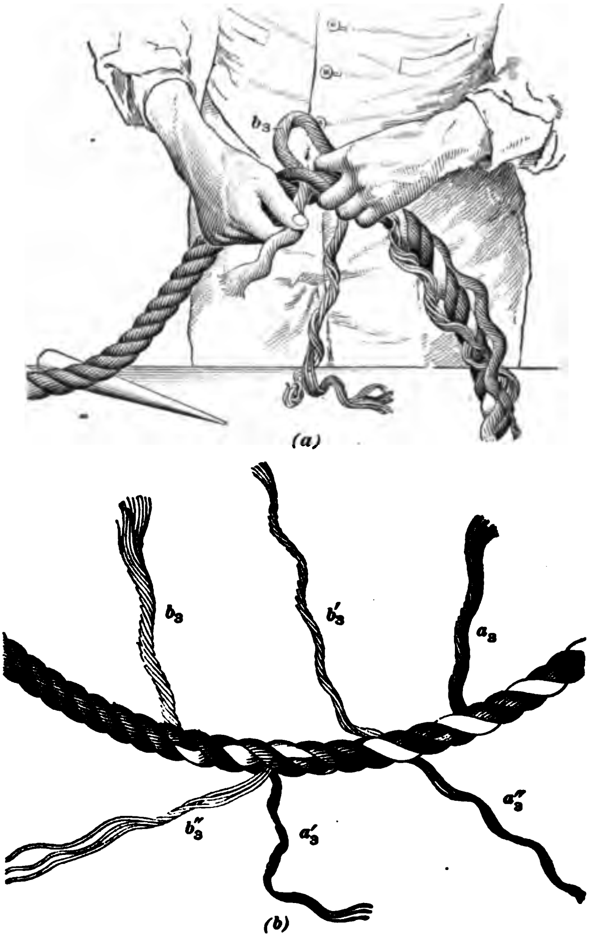


FIG. 37

Sometimes the overhand knot is made without first thinning the strands and then split, and the half strand put through as described; but the surface of the splice is never as smooth as by the other method, which, for strength and neatness, is generally preferred.

79. Making Eye Splice.—Another splice, and one that is as common and useful as the two already described, is the eye splice illustrated in Fig. 39. To begin this splice, the end of the rope is unlaid about as far as for the short splice, and bent into the required size of eye, as shown at (*a*). The end of the middle strand *a* is then tucked under one of the strands of the standing part *b*, the necessary opening having previously been made with the marlinspike, and pulled tight, getting what is shown at (*b*). The strand *c* is now pushed, from behind, under the strand on the standing part *b* next above that under which the strand *a* was passed, so that it will come out where *a* went in, as shown in (*c*). The third strand *d* is then passed under the remaining free strand *c* in the standing part *b*, next to the one under which *a* was passed. The strands are now pulled taut, and from each one-third of the yarns are cut out and each strand is again tucked under the second strand in front of it as shown in (*d*). After this operation is repeated, the rope is given a good stretching and the ends are cut off.

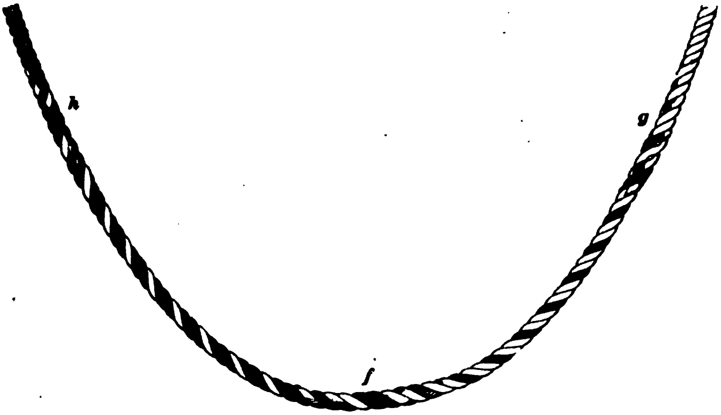
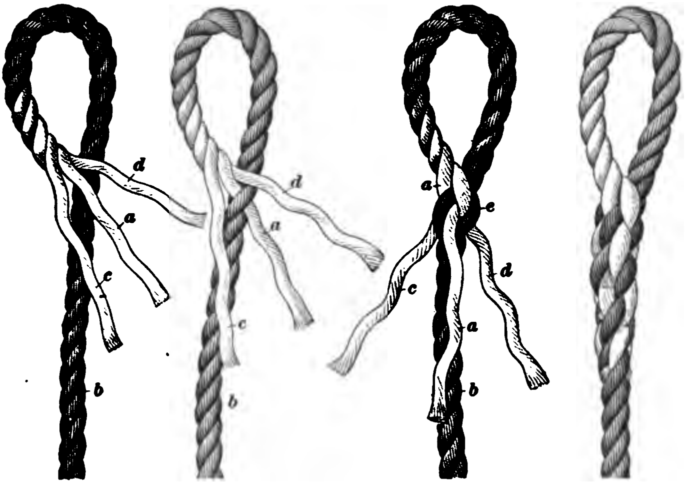


FIG. 38

80. Knots, Bends, and Hitches.—In Fig. 40 are illustrated a few methods of making knots and bends, applying slings and ropes to hooks, barrels, etc., and a few other knots and hitches useful to those engaged in workshops. Should a rope be too long for some temporary purpose, it may be arranged with a *bight* as shown in (*a*); if several bights are laid up to shorten the rope to the required length, the standing part is passed through and over the ends of all, and the rope is pulled tight. In (*c*) is shown how a sling or strap should be applied to a hook when the rope spreads away to its load; this hitch will prevent the sling from slipping in the hook, in case the load should come in contact with some obstruction while being hoisted. In (*b*) and (*d*) is shown how a smaller rope should be secured to one of greater diameter.



(*a*) (*b*) FIG. 39 (*c*) (*d*)

81. The **Blackwall hitch** is illustrated in Fig. 40 (*e*); except for very light loads, this should be made, with a **double hitch**—that is, with the end twice around the hook—as in the figure. Experience has proved that this is the safest way, since with only one turn, the end is liable to creep when subjected to a heavy pull, expecially in damp weather, when the moisture absorbed by the rope acts as a lubricant. When a rope is too long to conveniently secure its ends to a tackle, a bight of it twisted as in (*f*) is very handy and useful. To make this hitch, commonly called a **cat's paw**, take hold of the rope with both hands at places about 2 feet apart, and twist it two or three times each way; then apply the ends of the loops thus

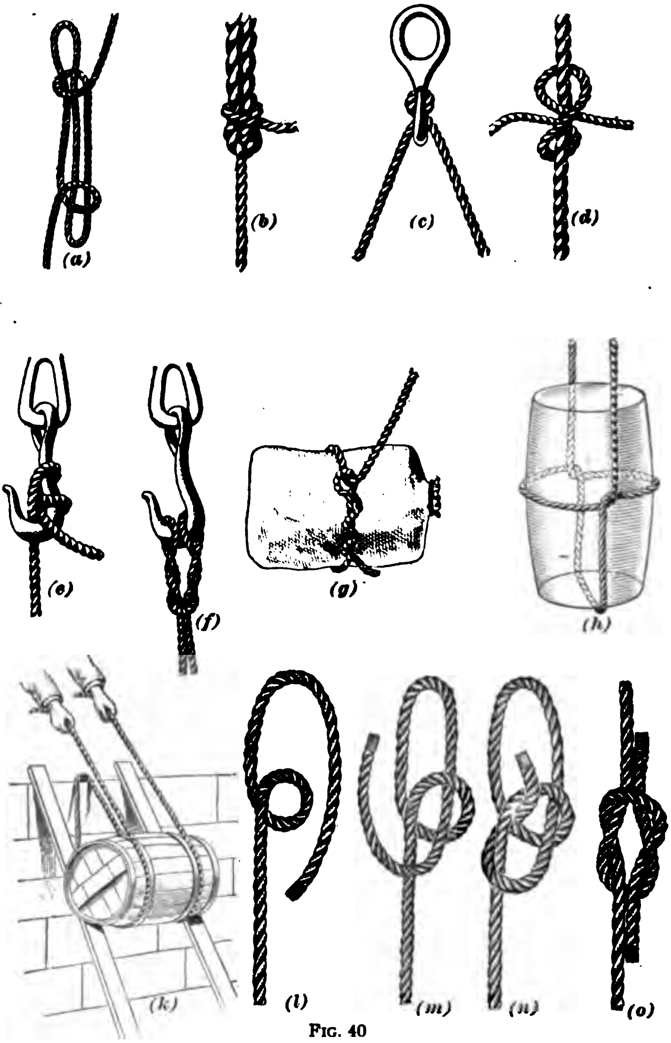


Fig. 40

made to the hook. The twisting prevents the rope from becoming jammed, and the hitch is very easily undone. In (*g*) is illustrated a **timber hitch,** so simple that explanations are unnecessary. In (*h*) is shown how to apply a rope to a barrel or similar vessel when it must be hoisted in a vertical position. In (*k*) is shown what is known as a **parbuckle;** this hitch is used for raising a heavy cask or similar load with a single length of rope.

82. A very useful knot, the making of which should be understood by every mechanic, is shown in Fig. 40 (*l*), (*m*), and (*n*); by seamen, this knot is known as the **bowline knot.** When making this knot, a bight, turn, or loop, as shown in (*l*) is first made, after which the end is passed through the bight as shown in (*m*). The knot is completed by passing the end around the standing part and through the bight again. The finished knot is shown in (*n*). The **square knot,** shown in (*o*), is probably the most common knot used to tie two ropes together.

ERECTING
(PART 2)

FITTING AND INSPECTION OF WORK

FITTING OF PARTS

1. Classification of Fits.—Two pieces of work may be tightly joined together either by pressing or driving one of them into or over the other; or one part may be expanded by heating, placed over the other, and allowed to cool, when it then tends to return to its original size; and, if the proper allowance has been made, a very rigid and durable joint is the result. Fits made by driving the pieces together are called *drive fits;* those in which the pieces are pressed together *press fits;* and those which are effected by heating, *shrink fits.*

In addition to the fits enumerated, there are two other kinds, known as *sliding* and *running fits;* but in these, as their names imply, the parts fit loosely into each other, the bore being larger than the shaft or the equivalent, and no pressure being required to put the parts together. The former is sometimes spoken of as a *free fit,* and the latter, which is the easier or looser of the two, as a *bearing fit.*

2. Press, drive, or shrink fits, when properly made, produce excellent joints; but if a shop is equipped with presses and the character of the work permits it, the press fit is to be preferred, since it is the most easily as well as the most accurately made and the pressure applied can at all stages be observed by means of a gauge on the press. When no press is available, the parts

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may be driven together with hammers or rams. Sometimes, however, neither a press nor a ram can be readily applied,

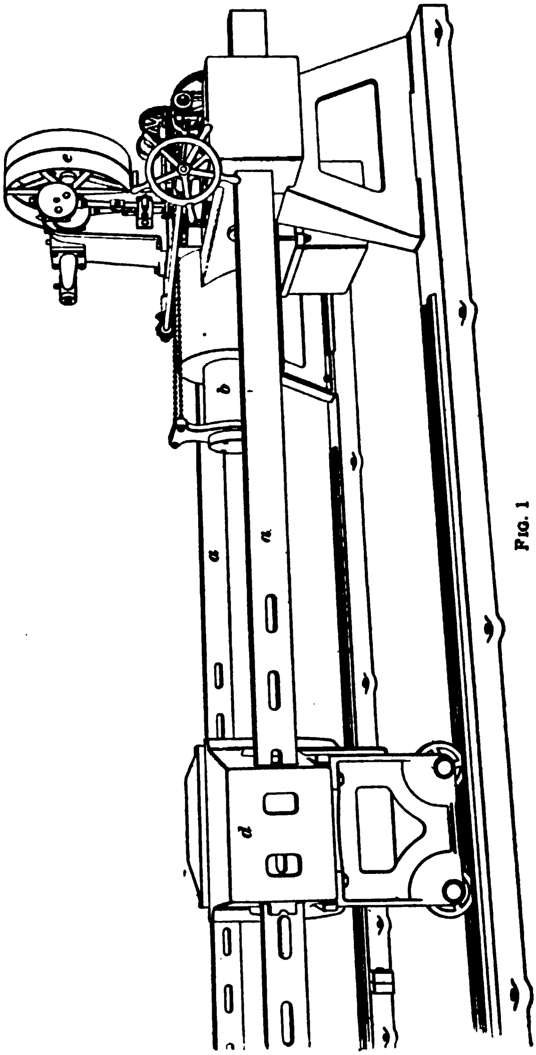

FIG. 1

and the shrink fit may then be used to the best advantage, as in making the joints of flywheels, shrinking locomotive tires on wheel centers, etc. In these instances, a link, bolt, or ring, as the case may be, is made a little shorter or smaller than the place in which it is to be located and is then heated until it goes freely into its position, after which it is allowed to cool, thus drawing the parts tightly together.

3. **Stationary Hydraulic Press.**—Fig. 1 shows a hydraulic press that is used for such work as pressing the cranks on engine crank-shafts and general pressing on or off in making press fits. It is made of from 200- to 400-ton capacity. The tie-bars *a* are placed on either side, so that the work can be lowered into, and lifted out of, the press with a crane. For use in railway shops, the tie-bars are placed one below the floor and the other overhead, thus enabling the rolling in and out of the car wheels or locomotive wheels. The same tie-rods, or similar ones, may be used with hydraulic jacks for portable-press work.

4. This machine will take 10 feet between the tie-bars and 25 feet between the ram and sliding head. The ram *b*, Fig. 1, is 14 inches in diameter, has a stroke of 4 feet, and is provided with a counterweight so that it returns automatically when the release valve is opened. It is supplied with a safety valve that can be set to open at a desired pressure, which makes it impossible to push more than a specified amount. The valve is locked in a box cast on the cylinder. The pressure gauge is graduated for tons pressure on the ram and pounds per square inch of its area. The sliding head *d* moves on a track, and is held in position by steel keys. The force pump is driven by a belt placed on the pulley *e*, and takes its water supply from a tank underneath, to which the water is returned.

5. **Portable Hydraulic Press.**—Fig. 2 shows a portable hydraulic press that will exert 100 tons pressure or more, consisting of a cylinder *a* and ram *b* with side bars *c* and cross-ties *d*, hand pump *e*, reservoir *f*, and gauge *g*. The side bars are held between the parallel lugs *h* on each side of the cylinder and are provided with slots suitably spaced into which keys *i* may be inserted. A pair of keys are inserted in corresponding slots at both ends of each side bar, the cross-ties bearing against

one pair of keys while the cylinder bears against the other pair. The pieces of work *j* and *k*, which are to be forced together, are placed between the cross-ties and the ram and maintained in their proper positions, if necessary, by being blocked up from the floor or supported by a crane. Pressure is exerted by means of the hand pump, operated by the lever *l*, which draws the fluid from the reservoir and forces it into the cylinder, driving the ram forward against the work. The opening of a valve relieves the pressure and allows the fluid to return to the reservoir. A second lever *m* enables the ram to be ratcheted back to its starting position.

6. **Straight Press Fits.**—Press fits may be classified as *straight* and *taper*. In a straight press fit, the internal piece, as a shaft, must be only enough larger than the hole to insure the development of sufficient friction between the two pieces to hold it there securely when pressed home. The amount of friction is judged by the total pressure in tons on the piston of the press that is required to force the pieces together. The allowance that must be made—that is, the difference in the diameter of the two pieces required to insure a pressing together at a given pressure—cannot be accurately calculated, as the pressure depends on a number of variable factors whose values can only be approximately determined. Some of these factors are the length of the hole compared with its diameter, the relative smoothness and exactness of the surfaces that are to be joined, the amount of metal and the manner of its distribution

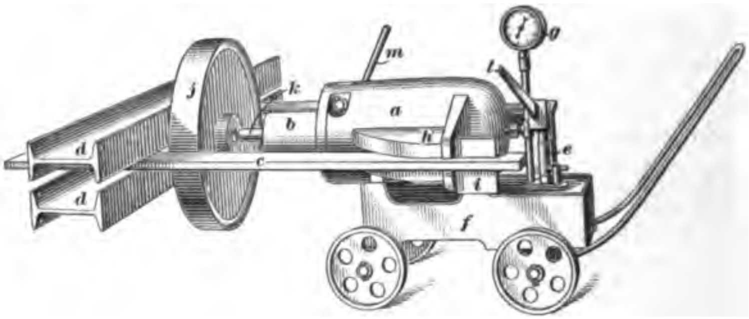

FIG. 2

around the hole in the external piece, and the character of the material. Experience, judgment, and experiment must therefore be largely relied on in work of this kind. In making a press fit the two parts should, as a rule, be lubricated with a heavy oil or grease, to prevent cutting, which might destroy the entire fit on both pieces. White lead is often used instead of oil.

7. **Influence of Temperature on Fits.**—If standard 1-inch cylindrical plug-and-ring gauges are tried together when they are at equal temperatures, the plug can only be pushed through the ring by exerting considerable force, since the size of each gauge is so near that of the other as to make the fit almost perfect. If the ring is held in the hand a few minutes, it will become larger and the plug can be easily pushed through it; if the plug is dipped in cold water and the ring warmed, the difference in size is so increased that the plug will fall through. From this experiment it is seen that metals expand when heated and contract when cooled.

8. **Allowances for Different Fits.**—The amounts allowed for various kinds of fits are treated in a general way in the following articles and table. Running fits for work less than 1 inch in diameter may be made by making the internal piece .0015 to .002 inch under the size of the hole, while a 2½-inch shaft may be as much as .005 under size. Drive fits are spoken of as tight and easy. The values given in Table I are for tight fits; the allowance for easy drive fits may be taken as one-half of that given.

9. In Table I, the allowances given for different fits represent the average allowances made in several good shops; but the conditions prevailing in the work being done govern the amount of force necessary to force two pieces together. For this reason the pressure necessary to push the parts together is seldom given in a table of allowances. For force fits, the shaft must be made larger than the bore by the amount given, and for sliding and running fits, smaller by the amount given.

10. The pressure required to force the work home varies with the allowance made, the character of the surfaces, the material, and the degree of hardness. The following examples

taken from practice give a general idea of the relation between pressure and fit allowances:

Two crankpins were required to go in holes 5 in. × 8 in. at 50 tons pressure. The pins were turned .003 inch larger than the diameter of the holes and went home at a pressure of 45 and 48 tons, respectively.

A car wheel with a bore 4$\frac{7}{8}$ inches in diameter and 7 inches long required a pressure of 30 tons to force it over the axle, an allowance of .007 inch having been made.

11. Taper Press Fits.—For some purposes, the taper fit is preferable to the straight fit. In a taper fit, the hole is bored tapering, frequently $\frac{1}{16}$ inch per foot, and the internal piece is turned to the same taper as the hole, or in the practice of some, an increase of .001 of an inch to the inch of length is allowed; that is, if the large end of a hole 20 inches long measures 15 inches, the large end of the internal piece would be made 15.020 inches in diameter. If the hole is very long, the amount allowed may be made less than .001 inch per inch of length.

TABLE I

ALLOWANCES FOR DIFFERENT FITS

Diameter Inches	+ Allowance on Shaft Inches			− Allowance on Shaft Inches	
	Press Fit	Drive Fit	Shrink Fit	Sliding Fit	Running Fit
1	.001	.00075		.001	.002 to .004
2	.002	.00075		.002	.004 to .006
3	.002	.00125	.00225	.003	.006 to .010
4	.002	.00125	.00300	.004	.007 to .011
5	.003		.00375	.005	.008 to .012
6	.003		.00450	.006	.009 to .015
7	.003		.00525	.007	.011 to .017
8	.004		.00600	.008	.012 to .018

12. Taper fits are sometimes made in the following manner: The hole in a hub, wheel, or crank is first bored with a taper of, say, $\frac{1}{16}$ inch per foot. A hollow cast-iron plug is then turned or ground to correspond to the hole and used as a gauge to which the inside of the hole is scraped until it is true and round. The pin or shaft is then accurately fitted to go in freely to within a certain distance of its final location, generally from 1 to 4 inches; it is then pressed home.

The following example taken from actual practice serves to illustrate the method of making taper press fits. An engine shaft 22 inches in diameter had a shoulder on each end for its flywheel and crank, respectively. The flywheel had a bore 30 inches long which was scraped so that the shaft, which was tapered $\frac{1}{16}$ inch to the foot, would slide to within 4¼ inches of its location. The shaft was then pressed in the remaining distance. The bore in the crank was 18¾ inches in diameter and 14 inches long; the shaft, which was tapered $\frac{1}{16}$ inch to the foot, was fitted to go within 3½ inches of the shoulder and was then pressed home. Similarly the crankpin, which was also tapered $\frac{1}{16}$ inch to the foot, had a bearing 9¾ inches in diameter, and 11 inches long and was fitted so as to go within 2⅛ inches of its seat in the crank, being pressed on the remaining distance.

13. Shrink Fits.—In the absence of a press, the shrinking process is often resorted to, but in general it is neither as safe nor as satisfactory. In this process the internal piece is made larger than the hole it is to go into, and the external piece is then expanded by heat to allow the internal piece to be easily slipped in.

The amount to allow for a shrink fit is largely a matter of judgment, in which the material and the construction of the article must be taken into consideration. Krupp allows .01 inch to the foot of diameter in shrinking on locomotive tires, while American builders allow a little more, .012 inch in 1 foot being common practice. The values given in Table I for shrink fits allow .009 inch to the foot, which is a little lower than the values just mentioned. Care should be taken not to allow too much, since either the external piece may pull itself apart or the internal piece may be crushed or distorted.

14. Heating Work for Shrink Fits.—There are many ways of applying the necessary heat for shrinking purposes. In some instances the piece to be heated is supported by firebrick or otherwise over a suitable fire, perhaps being covered with sheet iron or asbestos to assist in retaining the heat. Again, a ring of gas pipe may be provided with holes projecting radially inwards or outwards as required, the jets of flame impinging on the work. If a large number of duplicate pieces are to be assembled, regular furnaces may be employed.

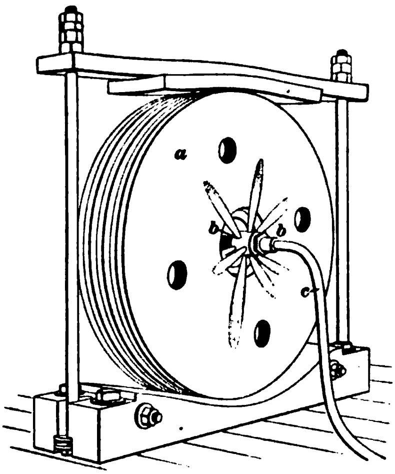

Fig. 3

A very convenient burner for heating parts in making shrink fits is shown in Fig. 3. A piston *a* is clamped between two wooden pieces, as shown in the illustration, and a gas burner *b*, which embodies the principle of the Bunsen burner, is supported centrally in the piston-rod hole. The burner has a number of holes in its circumference producing as many jets of flame as there are holes, which strike the surface to be heated. An ordinary rubber gas tube *c* connects the burner with a gas pipe on the wall.

15. Sectional Keys for Shrinking.—In shrinking together two pieces that have key seats that must line with each other, a device known as a sectional key may be advantageously used for alining the pieces. One form of this device is shown in Fig. 4. Two tapered side keys *a* and *b*, having handles *a′* and *b′* of suitable length, are placed in the two key seats of the two parts that are being shrunk together; and when these parts are in place, a tapered key *c*, with a long handle *c′* is then driven in between them, thus forcing the side keys against the sides of the key seats and alining them. When the work has cooled off, the device is removed, and the permanent key fitted and driven home.

16. Examples of Shrinking.—To shrink a crankpin in, the pin is turned to the required size and the crank is then heated sufficiently to allow the pin to enter freely. Care must be taken here to guard against the pin sticking in the hole before it is clear in. A heavy sledge should be provided on both sides of the crank, as the pin may require a little driving to carry it clear home. If the crank should cool too rapidly, the pin must be backed out as quickly as possible. When once in place, the pin should be kept cool by applying waste soaked in cold water or by keeping a stream of cold water flowing on the pin. If the pin gets hot, it may expand the hole and the fit will then not be as tight as was intended.

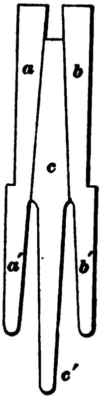

Fig. 4

17. The shaft should be blocked up at a convenient distance from the floor, with the key seat up. The crank should be heated until the bore shows sufficient expansion to go on the shaft easily. If the crank is heavy, it should be picked up by a crane in such a position that the key seat will be on top, to conform to that in the shaft. All dust or dirt should be carefully brushed from the crank, which should be quickly shoved up to the shoulder on the shaft, and a temporary key, fitting sidewise, should then be lightly driven in to keep the key seat in line. Means should be provided for holding the crank against the shoulder, or it may slip back and grip the shaft so tightly that it can never be brought up into its correct position. The permanent key may be fitted after the crank is cooled.

INSPECTION OF WORK

18. Raw and finished materials are frequently inspected in testing laboratories, inspection bureaus, or by inspection engineers. All goods inspected are marked with a label or trade-mark. Among the items usually inspected by these firms are rubber-covered cables and wires, porcelains, cements, hardware, tubing, sheet steel, conduit, steels of all kinds, castings, electrical apparatus, etc.

19. While all the large concerns have their own inspection departments they are obliged to engage outside experts from time to time, either because their own experts are not well qualified to pass on certain raw materials; because a preliminary inspection must be made at a place which their own experts cannot reach readily; or because of the requirements of the customer.

The building up of an efficient inspection corps requires a long time and is expensive, and for these reasons small concerns frequently find it to their advantage to engage the services of reliable inspection bureaus.

20. Inspection of Raw Materials.—The work of inspection may be divided into three kinds, inspection of raw materials, inspection of work in progress, and inspection of finished products.

21. As an aid to the purchase of the proper raw materials and their subsequent inspection when received, many of the larger concerns prepare so-called purchasing specifications, which set forth the physical requirements to be met, tests, guarantees, etc. Where an extensive variety of subjects is covered, the preparation of such specifications is a never-ending work of tremendous magnitude, as the list must be constantly revised and augmented. Some items do not lend themselves to a complete description by specification; for example, lubricating oils for shafting and machine tools; felts of the proper elasticity or springiness; articles of any kind with the correct finish, etc. A reference sample of each item of this kind is usually kept in a storeroom of approved materials, where it can be used for comparison as consignments are received from time to time. Similar samples may likewise be forwarded to suppliers for their use. On the receipt of materials at the works, they are inspected and tested as set forth in the specifications or otherwise deemed necessary.

INSPECTION OF MATERIALS RECEIVED

Purchasing Agents' No.____________ No.____________
Requisition No.____________ Date____________
From Whom Purchased________________________________
Description

Quantity	The Storekeeper is notified that the articles listed below have been $\begin{cases}\text{accepted}\\\text{rejected—defects are stated on reverse side}\end{cases}$

Signed________________________

FIG. 5

22. Fig. 5 shows a form of inspection blank adapted to material, whether raw or finished, purchased outside and inspected on its arrival. On this blank a space is provided for the number of the card, the date, the purchasing agent's order number, the requisition number, and the name of the firm from whom the articles were purchased. Under the word quantity, the inspector writes the number of articles that have been inspected. If they are satisfactory, a line is drawn through the word "rejected" and the blank is signed. If the goods are not satisfactory, a line is drawn through the word "accepted," the defects are listed on the reverse side of the blank, and the blank is signed. All materials falling short of the standards set by the specifications are rejected and the suppliers notified at once, so that there may be the minimum loss of time in replacing them.

23. Limits of Accuracy Required in Finished Work. In the shop, the dimensioned drawings are largely used by the shop inspectors. Formerly, it was the custom to place on drawings single dimensions only; for example, if a shaft was to be 3 inches in diameter and 10 feet in length, these dimensions were specified on the drawing. But it is beyond human skill to make a shaft absolutely 3 inches by 10 feet; and, as a matter of fact, such accuracy would not be required even if within the limits of possibility. The shaft will, when completed, be found either a little larger or a little smaller than the exact dimensions, and experience will determine just how great the variations may be without making the piece defective. This being the case, the permissible allowance both above and below exact size should be given on the drawing. When this is done, not only will the workmen have a guide to work by, but the inspectors will have one as well, and there will be no cause for perplexity on the part of any one connected with the work as to whether or not it should be passed.

24. **Inspection of Work in Progress.**—For best results, all work should be inspected as it progresses through the shop, if possible while actually being machined, assembled, or otherwise worked on. This course is recommended in preference to waiting until a piece is finished, for frequently errors may thus be caught before much material has been spoiled. In many cases it will be unnecessary to inspect every piece, as for example in screw-machine or other automatic or semi-automatic work. A few pieces inspected at the beginning of a job, to see that the dimensions check with the drawing, and a few additional pieces inspected as the work continues, to guard against wearing of the tools, will be sufficient. Where a piece undergoes a sequence of operations, each operation being dependent on the accuracy of the one preceding, a check on the first operation will prove sufficient.

25. **Inspection Bench, Rooms, and Tags.**—When apparatus or parts are manufactured in large quantities, use is made of dies, limit gauges, templates, etc., and such inspection is therefore a comparatively simple matter. In many instances, it is only necessary that certain dimensions be exact and these alone are checked. Where material cannot be inspected during

its manufacture, it is a good plan to have it delivered to an inspection storeroom. Here it can be inspected for quality as well as checked for quantity. When the work is too bulky to permit this to be done, it should be sent to the inspector's bench or inspected while on the floor near the machine on which the work is done. When large or medium-sized work is made in quantities, a serial number may be assigned to each piece and this number placed on the time slip or job ticket of each workman who is engaged on the job. In this way any defect may be traced back to the right workman regardless of the elapsed time between manufacture and inspection. Inspection tags should be used after each inspection unless the pieces are otherwise marked by an inspector's stamp, and a single tag may often be employed for a quantity of small items. Considerable aid may be rendered the inspection force by the manner in which these tags are designed. They should not consist simply of a few ruled lines on which the inspector is to write the name of the piece, the date of inspection, and sign his name at the bottom. On the contrary, a list of the vital points to be watched by the inspector should be printed in the form of questions which can be answered, wherever possible, by a simple *Yes* or *No*. This is illustrated by the tag shown in Fig. 6, used in connection with the testing of railway motors. A scheme of this kind will prove of the greatest value, especially when the inspector is comparatively new at the work. Where the work is of miscellaneous character, the plain tag must, however, be used.

26. Judgment Required of Inspector.—In addition to all rules, helps, or guides for the assistance of inspectors in their work, judgment must at all times be used by them. A knowledge of the application to which each piece undergoing inspection is to be put, is almost essential if it is to be passed or rejected on its real worth. If the piece is a rough casting or forging and no finish is required, the variation from the drawing may be very considerable, perhaps a quarter-inch, or even more if the piece is of large size, and no harm will probably be done; in fact, any expense incurred in bringing the piece to the size specified on the drawing would be an absolute waste of time and money. On the other hand, if the press-fit portion of a generator shaft was under inspection, a very close adherence to specified dimensions, possibly within .001 or .002 inch, would be necessary; otherwise, the shaft might, if under size by the amount stated, be actually loose when in position, or if oversize by an equal amount, might rupture the generator spider. It will thus be seen how large a part good judgment plays in inspection work; and, without going into further explanation, it may simply be stated that the same good judgment must also be used in dealing with the workmen. It is therefore quite evident that every mechanic has not the necessary requisites of a good inspector and that this position, being of equal importance with that of foreman, calls for the best men available.

COMPLETE MACHINE

Has frame been cleaned and painted inside?

Are field coils tight and is bore of field correct?

Are poles evenly spaced?

Do interpole bolts extend beyond pole face?

Are connections between field coils properly cleaned and insulated?

Has flame-proof braid been removed from brush-holder leads and replaced by tape?

Are housings entirely free from dirt and core sand?

Do bearings and housings fit and is alinement correct?

Are oil grooves chipped in cells?

Is drain hole provided for waste oil?

Are brushholders properly spaced and is the brush tension correct?

Are brushes parallel with commutator segments?

Are all covers properly fitted?

Is pinion tight on shaft and key properly fitted?

Does gear case clear gear?

Did commutator develop high-bar on test?

Serial

Order

Inspected by

FIG. 6

27. Study of Defects Disclosed by Inspection.—If the full value of inspection is to be obtained, a careful study of all defects found by the inspectors must be made. To this end daily reports should be forwarded by each inspector to the head of his department, who should classify them in various ways according to classes of apparatus and parts, manufacturing departments in which they occur, also as to whether due to design, workmanship, material, clerical errors, changes made by purchaser, etc. Such a complete analysis of defects will indicate to those in authority where the troubles lie and how serious they are, with a view, first, to correcting the defects before the apparatus leaves the shop, and, second, to take such steps as will prevent their recurrence. Besides the direct money loss due to various defects in apparatus, there is also the loss in output, the demoralizing effect on those engaged in the work, the delay in shipments and, if the defect gets past the inspection force, the effect on the purchaser. It is an axiom of every business concern that it pays to advertise and the best possible advertising medium is a pleased customer. It is equally true that a displeased customer can sometimes offset the good effect of large amounts spent in advertising.

EXAMPLES OF ERECTING

ERECTION OF LARGE WHEELS

28. Lining Up Fylwheel Shaft.—Large flywheels, rope wheels, gear-wheels, and other similar wheels are usually assembled in the erecting pit. The assembling and machining of the rim of a large built-up flywheel is an excellent example of the use of the erecting pit. The following method of doing this work may be used: Parallel bars *a*, Fig. 7, are bolted opposite each other to the plates surrounding the mouth of the pit, and temporary bearings *b* that will bring the center of the shaft *c* about 30 inches above the floor level, are placed on top of the parallel bars so that they are fairly in line with each other. The shaft *c* with the hub *d* on it is now picked up by a crane and lowered into the bearings, which are properly

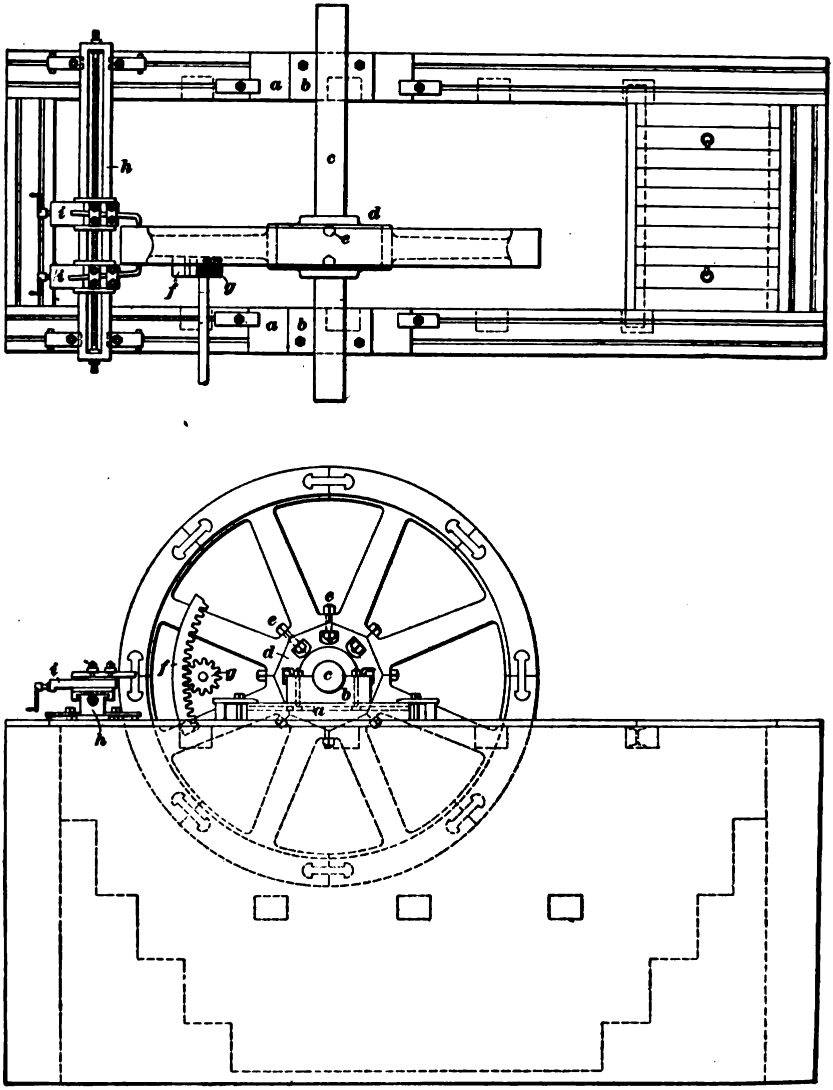

Fig. 7

alined to suit the shaft. The bearings, which need no caps, are now bolted down to the parallel bars. Another method of setting up the work consists of blocking up the shaft until it is level; the bearings, which are considerably larger than the journals, are then shifted into place, bolted down, and Babbitt metal is poured into them around the journals.

29. Assembling Rim Sections of Flywheel.—All the faces of the sections of the rim having been properly machined prior to the erection, one section is picked up by the crane and gently lowered on the hub, to which it is fastened, by temporary bolts, while in a vertical position. The shaft is now revolved sufficiently to bring the next seat of the hub to a horizontal position, and after the fastened section has been securely blocked to prevent rotation of the shaft, another section is lifted into place and is attached to the hub and the first section. This operation is repeated until the wheel has been assembled. The holes in the arms and hub are now reamed one by one to match exactly, and the permanent bolts are then carefully fitted, driven home, and the nuts securely screwed up, as shown at *e*, Fig. 7.

30. Turning Sides and Face of Rim of Flywheel.—To turn the sides and face of the rim, means must be provided for revolving the flywheel. A common method is to bolt a large annular gear, which, for convenience, is made in short sections, to the arms of the flywheel. One of these sections is shown at *f*, Fig. 7. A pinion *g* is then placed in mesh with the gear and is driven either by a rope drive, by a belt from an overhead shaft, by an electric motor, by a small steam engine, or by a compressed-air engine, as is most convenient. A heavy bed *h* is then bolted across the pit; it may carry two slide rests *i* to allow both sides of the rim to be finished at once.

31. Polishing of Rim of Flywheel.—If the flywheel is to have the rim polished, a grinding rig carrying a suitable grinding wheel may be mounted on the carriage *i*, Fig. 7. The grinding wheel, which is driven in any convenient manner, is then fed slowly across the surface that is to be ground while the fly wheel is revolving at a suitable speed.

ERECTION OF LATHES AND PLANERS

LATHES

32. Systems of Erection.—The method of erecting lathes varies greatly in different shops and also with different sizes and designs. Some makers first plane the grooves in the headstocks and tailstocks to a gauge and then bore the boxes of the headstocks and the holes for the tailstock spindles, while others reverse the operation, first boring the boxes and the holes in the tailstock spindles and then planing the grooves in the bottoms of the headstocks and tailstocks. Both systems, or modifications of both, are frequently used in the same shop. The second system is generally used on small lathes, up to 18 inches swing, while in larger lathes the first-mentioned system is more common.

33. Seasoning Beds.—Where extremely accurate lathes, such as toolmakers' lathes, are to be made, the beds should be cast several weeks before they are to be used, and allowed to season. This seasoning consists in simply piling them in some convenient place in such a way that they will not be subjected to any outside forces, and allowing the stresses in the casting itself to become equalized. Where extremely accurate work is required, a roughing cut is taken off the surfaces to be planed and the beds are again allowed to season for a short time before being finished.

34. Machining Beds.—Lathe beds are generally finished on the planer. The **V** grooves, guides, or shears are usually planed to gauges. The outside edges of the bed and the flat top between the ways are also planed. After the work leaves the planer, the space between the grooves, the outside edge, and the flat top of the bed should be filed and polished as soon as possible, as they can be finished much easier and in less time immediately after planing than when the work has been exposed to the air of the shop for some time. The file takes hold of the freshly planed work better than it does after the surfaces have become slightly rusted. Some mechanics claim that a file does not take hold of the surface of a casting that has stood for some time after planing because the surface becomes covered with a thin coating of grease that is deposited from the air of the shop.

35. Testing and Scraping Beds.—The ways are usually tested by a straightedge and then scraped, or, if necessary, they are filed and scraped. However, one shop, in which small lathes are made in lots of from twenty-five to one hundred at a time, uses a special surface plate made as shown in Fig. 8 for each size of lathe. This surface plate has been fitted up with great care, so that both the top and bottom ways *a* and *b* match each other; it has a trunnion at each end and can be lifted by a chain block or air lift. The hoist is connected to the surface plate by a bail; that is, a yoke-shaped handle of such construction that it may readily be secured to the plate. The trunnions permit the plate to be turned with ease, either side up. The ways on the lathe bed are scraped to fit the grooves *a*, and the headstock, tailstock, and saddle are scraped to fit the ways *b*. The saddle is sometimes scraped to the ways on the bed.

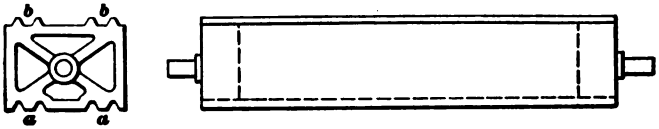

Fig. 8

36. Machining and Fitting Headstocks and Tailstocks.—The headstocks and tailstocks of small lathes are frequently made ready for the boxes and caps by milling, while the larger sizes are planed, machining them if possible by the gang system; that is, a large number are put on the planer table in line, and all are machined together. Jigs are usually provided for holding the pieces on the milling machine, and may also be employed on the smaller sizes when the work is done on the planer. The legs are fitted and bolted to the bed at any convenient time, but generally before the ways on the bed are scraped.

The machined castings for the headstocks and tailstocks are next sent to the fitter; the boxes and caps are then fitted to the headstocks, and the tops and bases of the tailstocks are fitted to each other.

37. Boring for Headstock and Tailstock Spindles. There are two general systems for boring the holes for the spindles in lathe headstocks and the tailstocks. In the case of small lathes, the boring is usually done first, after which an arbor is placed in the bored holes of both headstock and tailstock. This arbor is made to fit the holes in both accurately, and serves to bring them into line. While the pieces are held in line by means of the arbor, the **V** grooves are planed in them. In the case of larger lathes, the **V**'s are usually planed first and the headstock and tailstock fitted to the ways on the bed. After this, a special fixture carrying a boring bar is used for boring the holes in the headstock and tailstock. This fixture is constructed so that it holds the boring bar parallel to the **V**'s or ways of the lathe. A special jig may be used for holding the headstock and tailstock while boring, instead of putting them on the bed. After the boring is completed and the **V**'s are planed, the work of erecting actually begins.

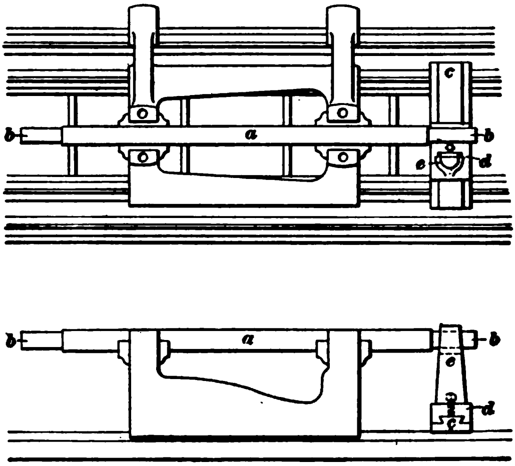

FIG. 9

38. Fitting Headstock and Tailstock to Bed.—Lathe erection differs somewhat in different shops, but the following may be taken as the general method of procedure: The bed, with the legs attached, is placed in position on the erecting floor and leveled until it is out of wind. The **V**'s or ways are tested by means of straightedges and suitable gauges. The headstock and tailstock are then scraped to fit the **V**'s.

When the headstock and tailstock have been brought to fit the **V**'s fairly well, their spindles are brought into alinement by means of proof bars, as shown at *a*, Figs. 9, 10, and 11. These proof bars fit the boxes of the headstock and the bore of the tailstock spindle. The ends *b* of the proof bars are finished by grinding to exactly the same diameter, so as to allow them to be used in making measurements for alinement.

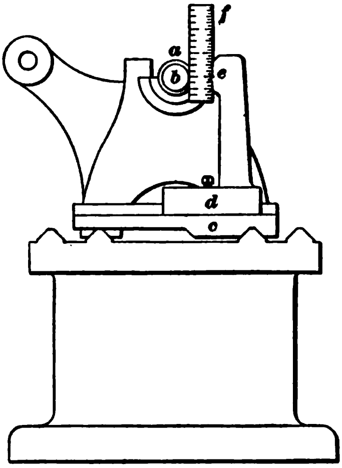

FIG. 10

39. When making measurements for horizontal alinement the special saddle *c*, Figs. 9 and 10, is used. This saddle is provided with a groove fitting one of the **V**'s of the bed, and carries a slide *d* to which an upright arm *e* is fastened. The headstock and tailstock with the proof bars in them are placed on the bed at some distance from the ends. The temporary saddle is placed near one end of one of the proof bars, and the slide *d* is adjusted until the feeling piece, as, for instance, the steel rule *f*, will just fit between the face of the upright *e* and the end *b* of the proof bar. The saddle *c* is then shifted to the other end of the proof bar, and the distance between *e* and the end of the proof bar tested, without disturbing the position of the upright. This operation is then repeated for the other proof bar. The manner in which the feeling piece goes in shows whether the headstock and tailstock are in perfect alinement in a horizontal plane. If not, the grooves that fit on the **V**'s of the lathe are scraped until the piece that is out of alinement is brought into perfect alinement. Sometimes a machinist's indicator or some form of micrometer head is carried on the upright *e*. Such a device as this serves to measure the amount that the spindles are out of alinement.

40. To test the vertical alinement of the spindles, a jack *g*, Fig. 11, may be placed on top of the parallel *c* and the screw adjusted until it will just touch one end of the proof bar. The parallel and the jack are then shifted to the other end of the proof bar. The manner in which the jack goes under the bar determines which way, if any, either end of the spindle is out of line. This method not only tests the alinement of the headstock and tailstock spindles in respect to each other, but at the same time tests their alinement with the ways or line of motion.

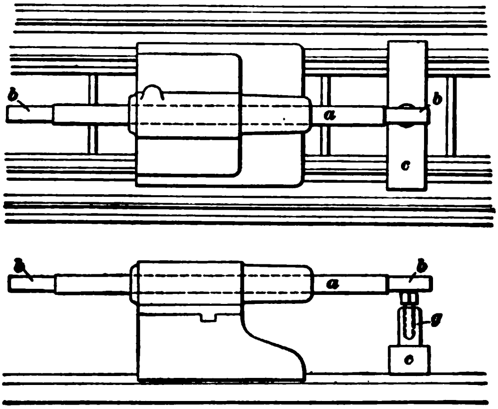

FIG. 11

41. Fitting Saddles.—After the headstock and tailstock are lined, the saddle is placed on the **V**'s and a round test piece *a*, Fig. 12, is placed against the cross-slide *b*. This test piece should be ground exactly cylindrical and should be long enough to project several inches beyond the sides of the saddle. An arm *c* is now fastened to the proof bar and the setscrew *d* brought in contact with the bar *a*. The arm *c* is then rotated to the opposite side, to the position shown by the dotted lines. If the screw *d* does not show the saddle to be square, it must be shifted by scraping the **V**'s in the saddle until the cross-slide *b* is at right angles to the **V**'s, as shown by the test bar *a* and screw *d*.

42. **Assembling Parts of Lathe.**—After the headstock, tailstock, and saddle are brought into alinement with the **V**'s, the tailstock spindle and anchor are added to the tailstock, and the spindle, back gears, feed-mechanism, and feed-reversing mechanism are placed in position on the headstock. The set-over screws must be in the tailstock while lining the tailstock spindle if the two spindles are to be brought into line with each other.

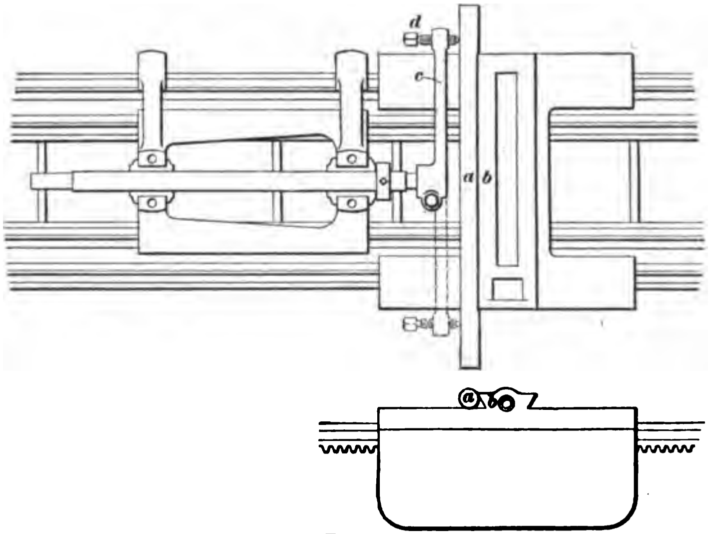

FIG. 12

43. **Fitting Apron.**—The apron is next clamped to the saddle and tested for alinement by using a proof bar placed in the lead-screw or feed-rod bearings. Measurements for alinement are taken from the bar to the edge and to the top of the bed. If necessary, the apron is brought into alinement by filing its top and back. The apron is then secured in position by screws, and the boxes for carrying the lead screw and feed-rod are placed

on special bearings provided on the ends of the apron proof bar. The boxes are then moved into contact with the pads on the bed, which have been provided to carry them. These pads have been previously planed, and the boxes are marked and then planed to fit on the pads, after which they are fastened to the bed, and the feed-rod, the lead screw, and the remainder of the feed-mechanism and screw-cutting mechanism are put in place.

44. Taper Holes in Headstock Spindles.—The taper hole for the center of a live spindle is put in by different methods; its accuracy is sometimes very intimately connected with the assembling or erection processes. Some makers prefer to rough out the spindle, particularly if it is a small one, and then to drill, ream, and hand ream the hole, after which the spindle is centered by the hole and trued outside, a plug having been fitted to the taper hole.

45. Another method that has many advantages is used extensively for large spindles. The spindle is centered and a steady-rest seat is turned on both ends, if it is to be a hollow spindle; the hole is then put through. Plugs are driven in both ends if the hole is larger than an ordinary lathe center, and the spindle is finished with the exception of the face-plate thread and the taper hole. The assembler or erector puts the unfinished spindle into its place, and if a large number of headstocks are to be finished, he places them successively on a lathe bed made for the purpose and provided with a taper attachment, and bores the taper hole true, smoothing it with a hand reamer. He completes the work by cutting the thread to fit the face plate. In large lathes built in small quantities, the headstock is mounted on its own bed for boring the taper hole in the spindle and for cutting the thread; a compound rest is used for boring the hole in case the lathe has no taper attachment. The process by which the spindle is finished in its own bearings has the important advantage that with reasonable care and skill on the part of the erector the taper hole and the thread will be concentric with the bearings of the spindle.

46. Patching Chipped Castings.—In the handling of heavy castings, chips or flakes are often knocked off by accidental collisions with other work. While the machine may not be weakened appreciably, such defects are unsightly, and for the sake of appearances should be remedied. There are compounds on the market especially prepared for this work. The compound is made up to the consistency of putty, and is pressed over the defacement and allowed to harden. When once hard, it adheres firmly and may be filed like iron. It then presents a metallic surface.

47. Inspection.—All machines are more or less defective, as it is practically impossible to make anything absolutely perfect. Knowing this, the builder establishes a limit within which the error will not materially affect the working of the machine, and furnishes the inspector with a list of such defects and their limits, with instructions not to allow a machine to pass until the errors have been brought within the allowable limits.

48. The tapered hole in the headstock spindle is tested by means of a proof bar, to see whether it is concentric with the spindle journals. This bar is ground tapering to fit the hole in the spindle and is cylindrical the remainder of its length. It may project a foot from the spindle for the smaller lathes and more, proportionately, for the larger ones. By revolving the spindle and applying the indicator to the bar at the mouth of the hole and again at the outer end, the amount of error is easily determined.

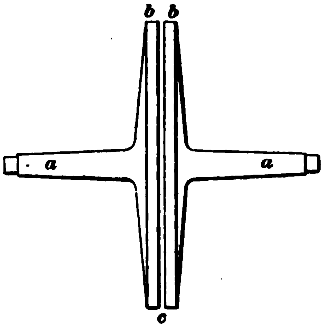

FIG. 13

The alinement of both spindles in reference to each other may be tested by means of the pair of disks shown in Fig. 13, which are made with taper shanks *a* that fit the taper holes in both spindles. The disks *b* are ground to the same diameter and are faced as square as possible. They are placed one in each spindle; the tailstock is then moved up to the headstock, and when the faces *c* of the disks are brought nearly in contact the amount of error is readily measured with a thickness gauge.

A pair of centers, having cylindrical ends exactly the same size, with the ends faced square, are sometimes used by the erector to determine if the spindles are in line. One is placed in each spindle, and the two, when brought up end to end, show very closely any error in alinement.

49. The leadscrew, being particularly liable to error, is tested for any deviation from the true pitch in lengths of 12 inches at different points along the screw. Gearing of all sorts is inspected and tested for alinement and smoothness of operation. The fits of all wearing surfaces are tested, as well as the fits of the various screws and binding and clamping fixtures. No part is neglected, and no defective material or faulty workmanship is allowed to pass.

The inspector is usually provided with a printed blank for reporting each lathe. The serial number stamped on the lathe appears on the report, which is filed in the office for reference should complaint be made or repairs ordered.

50. Filling and Painting Machines.—Most machines are finished by a coat of paint. The surfaces of the castings are cleaned first in the foundry scratch room, and any remaining dirt or irregularities and unevennesses of joined parts are removed during erection by chipping and filing so far as may be necessary to make a good surface. The shop painter next goes over the surfaces with a filler, which is a thick, heavy, very adhesive, and quick-drying paint. It is applied with a putty knife, as it is about as thick as very soft putty or freshly opened white lead. This filler hardens rapidly when exposed to the air. The filled surfaces are then smoothed by wetting and rubbing them with a piece of grindstone or of a broken emery wheel, or by simply rubbing them with coarse sandpaper. When the smoothing has been finished, one or two coats of paint of the desired color are applied. Green paint is preferred by some builders and shop superintendents, as it gives a lighter appearance to the shop than black paint. Green and even lighter paints are much used for machine tools, and if the painted surfaces are covered with a varnish that will resist oils, they are easily kept clean and the general appearance of the shop is thus much improved. Steel-gray metallic paint is preferred by some builders owing to the attractive appearance it gives to the machines.

PLANERS

51. Shop Erection.—In planer erection the principal points to be considered are that the method must be such as to quickly and cheaply assemble the parts so that they will all be in their proper relation to each other and that the alinement of the various parts will be perfect within the required limits. Small planers can be erected much easier than large ones, because there is less spring in their beds. When manufacturing small planers, the parts may be so accurately made by means of gauges and templets that they can be assembled and made practically interchangeable. In the case of large planers, the parts cannot be made interchangeable, as the bed depends on the foundation for its support, it being impracticable to make a casting large enough to insure perfect rigidity in the bed. Hence, in the case of large-sized planers, each machine must be treated by itself. All the points in the erection of a small planer are involved in the erection of a large planer, as well as many other complicating factors; consequently, the erection of a planer of this class will be given in detail.

52. Planers may be divided into three classes: *small*, which plane work up to 24 inches square, that is, in width and height; *medium-sized*, which plane work from 24 to 40 inches square; and *large*, which plane work larger than 40 inches square. Small-sized planers are usually provided with a single head for carrying the tool, the head being placed on the cross-rail between the housings. Most medium-sized planers have two heads on the cross-rail. The larger planers are all provided with two heads on the cross-rail and with one head on each upright.

53. Planers may also be divided into two classes in regard to their construction; that is, into those having double housings, or *closed* planers, and those having but one housing, or *open-side* planers. The erection of these types as far as the general principles are concerned, does not differ greatly; the erection of the closed type involves the bringing of the housings parallel, and hence planers of this type will be considered.

54. Precautions in Regard to Castings.—All castings for planers should be made from good close-grained iron. The castings for the table should be of a soft but tough nature, so that the upper surface can be planed true at one setting of the tool, for if the casting were hard it would wear the tool enough to throw the surface appreciably out of true. Very large planer beds, and occasionally large planer tables, are made in two or more pieces and joined by means of bolts and dowel-pins.

55. All the larger castings for the planer should be planed to carefully tested gauges, and every angular surface tested to make sure that the angle is correct. The work should be tested with a straightedge on the machine to make sure that the planer is not working concave or convex. Care taken in planing these parts will reduce the work of the fitter and erector. Long beds or tables that are made in sections should have their ends planed perfectly square and should be bolted together as securely as possible with fitted bolts and dowels. After all machine work is done, the erection proper begins.

56. Supporting of Bed.—The planer bed *a*, Fig. 14 (*a*), is supported on cast-iron parallel blocks *b* placed 6 or 8 feet apart along the whole length of the bed. Planed cast-iron wedges *c*, arranged as adjustable parallels, may then be placed between the parallel blocks *b* and the bed.

A better form of adjusting block used by some builders is similar to the block shown in (*c*). It consists of a base *a* having an inclined surface *b* on which the tapered adjusting block *c* slides. The top, bottom, and inclined surfaces are planed true. Adjustment is made by moving the adjusting block in or out by means of the adjusting screw *d*. The lugs *e* are slightly higher than the slide and act as stops when brought against the edge of the bed. A clamp jack *d*, Fig. 14 (*a*), is placed under the bed at each side just forward of the housings. This may be removed if necessary while putting in the driving gearing. The blocking under the uprights should be so arranged that

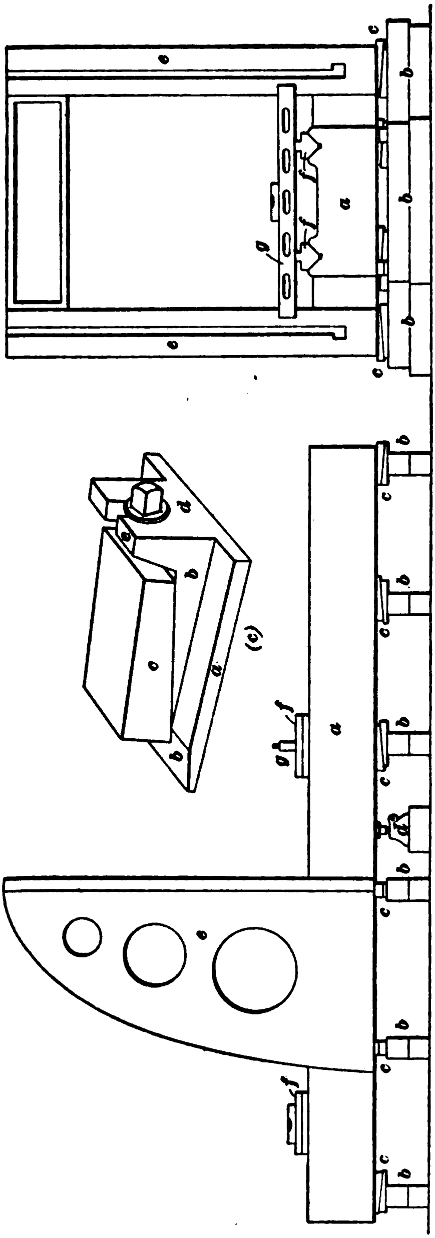

Fig. 14

it will not interfere with the driving and feed-mechanism during erection. As these details vary, the blocks must be arranged to suit each different machine. It is best to put the housings or uprights *e* in their places on the bed before the leveling operation, as the addition of their weight may throw the bed out of level again if they are placed in position afterwards. In some cases the uprights *e* are supported on erecting jacks in place of blocking, as this facilitates adjustment of the parts during leveling.

57. Leveling of Bed.—Several methods may be followed in leveling a planer bed, depending on the tools at hand. They all require considerable care. The process here described will give very good results if the work is carefully done. The leveling is done as follows: A pair of V-shaped parallels *f*, Fig. 14 (*b*), about 3 feet long, are placed one in each of the ways or V's of the bed. These parallels have been scraped as nearly true as it is possible to make them, and they may have center lines on them. A sensitive level is used on the top and one side of the bed is carefully leveled by moving this parallel, short distances at a time, over the entire length, adjusting the wedges under the bed where necessary. The other parallel is used in a similar manner in the other V, and by placing a straightedge across both of the parallels and using the level on it, the work is leveled crosswise. The operation of first leveling one side and then cross-leveling to the other is repeated until no further errors can be detected.

58. **Setting of Housings.**—The housings *e*, Fig. 14 (*b*), are now tested and brought exactly plumb by placing a straightedge across the blocks lying in the V's and using a large square on the straightedge. In the case of large planers having a very heavy cross-rail and heads, some makers do not attempt to bring the housings exactly plumb on their faces, but allow them to lean back .0005 inch for every foot in height, as the weight of the cross-rail and heads will bring the housings forwards somewhat, and this allowance will about correct the error. The housings are squared both sidewise and in front, and the distances between them at the top and bottom are made equal.

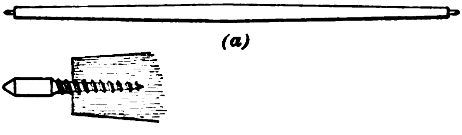

Fig. 15

59. In gauging the distances between housings on a large planer, use may be made of a large adjustable pin gauge illustrated in Fig. 15 (*a*), which consists of a bar of white pine or some other light wood, fitted with a screw inserted endwise at each end. The bar should be 1½ to 2 inches shorter than the distance between the housings, and the screws may be simply 2½-inch wood screws with their heads filed off and the ends pointed and rounded, as shown in detail in Fig. 15 (*b*). The bar may be tapered from the center toward both ends, and in

the case of a rod for measuring a distance of approximately 10 feet, the wooden bar must be about 1½″×2½″ in the center. The advantages of the wood are that it is lighter than metal and that it is affected less by expansion and contraction due to varying temperature. No fixed distance is made between the housings on a large planer, the only object being to make it the same at the top and the bottom, and this device becomes only a large inside caliper.

60. During the operation of setting the housings parallel the gauge is first set to the smallest distance, whether it is at the top or bottom. The gauge is then moved to the wider end and the approximate difference between the two ends found by putting strips of paper or sheet metal between the end of the gauge and the housing. The housing bolts are then slackened off and strips of paper or thin sheet metal placed between the bed and the housing so as to bring the latter parallel to the other housing when the bolts are tightened. The thickness of the material inserted will depend on the amount the housings are out of parallel. This process is repeated until the housings are correctly set, the gauge being adjusted from time to time as necessary. The thickness of the strips inserted is then measured with a micrometer and an equal amount of metal filed or scraped from the side of the bearing surface opposite the side where the strips were placed. The bolts are then tightened and the distances again gauged. If now the housings are found to be the same distance apart, top and bottom, the adjustment is correct.

After the housings are perpendicular to the bed and parallel to each other, the arch, or top rail, is squared off to the length indicated by the gauge and bolted in position. In the case of large planers, no attempt is made at interchangeability in this respect, but each top rail is fitted to the planer on which it is to be used.

61. Placing Table and Driving Mechanism.—The ways on both table and bed are finished by removing all loose metal and scraping them until they fit and have good wearing surfaces. The driving mechanism and the table are then put in place, after which the table rack is planed to the required thickness and secured to the table.

62. Squaring Cross-Rail.—The cross-rail *d*, Fig. 16, must be set true to the **V**'s in which the planer table slides. One way of accomplishing this is illustrated in the figure. The table *a* is run back far enough to expose the **V**'s under the cross-rail and two cylindrical pieces *b*, *b'* of exactly the same diameter are laid in the **V**'s. A square-nosed tool *c* is set flat in the tool post and brought over one of the cylinders *b*. The tool is then adjusted until a feeling piece can just be moved between the cylinder and the tool. Another method is to use a machinist's indicator in place of the tool, and bring the point of the indicator in contact with the cylinder. The tool or indicator is now run to the opposite side of the planer and central over the cylinder *b'*. If *b'* is found to be higher or lower than *b*, the error must be corrected by adjusting one end of the cross-rail up or down, which may be done in a number of ways. Some makers find that a sufficiently close adjustment can be obtained by moving one of the gears *k* or *k'* one tooth, so as to raise or lower one end of the cross-rail this amount. Other makers leave one of the pinions *m* or *m'* loose until the adjustment has been made, after which they key it in place. Still others attach one of the pinions, as *m'*, by means of a setscrew, as shown at *n*, the setscrew being tightened after adjustment.

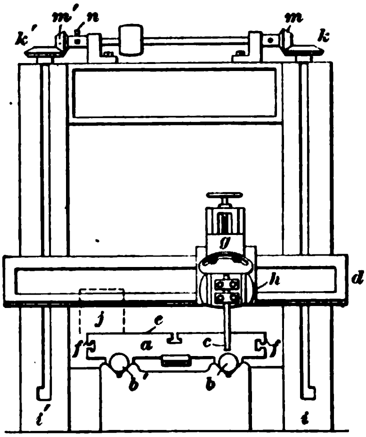

FIG. 16

63. As the cross-rail is moved up and down by two screws operated by the gears *k* and *k'*, when one end of the rail is found to be low, it should be raised the proper amount. When the setscrew method of adjustment is used, this can be accomplished by loosening the screw *n* and turning the loose pinion *m'* the desired amount. By repeating these trials the cross-rail can be so adjusted that the tool and feeling piece, or indicator, will give the same reading over both cylinders *b* and *b'*. The vertical screws carrying the cross-rail should always be so adjusted as to raise the cross-rail, as this will take up any lost motion or backlash between the nuts, the elevating screws, and the uprights. Hence, it is always better to raise the low end of the cross-rail rather than to lower the high end. The feed-mechanism and the mechanism for raising the cross-rail by power, together with the oiling device, are all put in place and tested, after which the various planer motions are tested to see that they are within the allowable limits of error.

After the cross-rail has been adjusted, a light cut should be taken over the top of the table. The head *g*, Fig. 16, should then be set vertically by means of a square. On very large planers the table is not trued in place by the manufacturer, this being done after the planer is set up in the purchaser's plant.

64. **Preparation for Shipment.**—Small and medium-sized planers are generally shipped with the principal parts in place and all bright parts coated with slush oil, or some other protective coating, to prevent rusting. The lighter and small parts are crated to prevent breakage and the whole mounted on skids for convenience in handling. Larger planers are taken apart, the smaller pieces being boxed and the fitted faces of the larger ones crated. Finished surfaces should be slushed or given a protective coating before shipping. The smaller planers have their tables carefully trued in place before leaving the manufacturers, but the larger ones are usually shipped with the table just as it comes from the planer on which it was finished.

65. **Erection in Place.**—The top of the foundation for a large planer should be smooth and as near level as it can be made. The bed is placed in its correct position on the foundation and leveled by the use of leveling blocks or by shims placed between the bed and the foundation. A high-grade level should be used and the adjustment continued until the bed is level lengthwise and crosswise after the housings, arch, and cross-rail have been bolted and keyed in place. The cross-rail elevating mechanism is then placed in position.

The cross-rail is then adjusted until it tests perfectly level with respect to the **V**'s. The feed-mechanism may meanwhile be put in place. When the driving and feed motions are working satisfactorily, the **V**'s of both the table and bed are cleaned and oiled and the table is placed in position. The table is then tested and if it has not been already done, the top and working sides of the **T** slots are carefully trued. The head or heads on the rail are then set to plane square with the table. Each head is set as nearly vertical as possible by placing the beam of a square on the table and adjusting the side of the down-feed slide to its blade. Cuts are then taken down the sides of the table by side tools. The vertical setting of each head is adjusted, after each cut until the blade of a large try square will hold a slip of tissue paper at each end of the blade on the top of the table while the inside of the beam is held against the side face of the table. The setting mark *h*, Fig. 16, is then drawn on the saddle so that it coincides exactly with the zero mark of the graduations on the head. If the setting mark has already been placed on the saddle it is best to go through with the test to prove its correctness.

66. If the planer is provided with side heads on the uprights, they may be set from the table and tested by clamping a casting as indicated by the dotted lines at *j*, Fig. 16, to the surface of the table and planing the vertical surface true with the side head. The top is roughed off with a tool in the cross-rail head, and finishing cuts are taken over the top with the horizontal feed of the side head which is adjusted until the two planed surfaces are exactly square. The setting mark is then scribed on the saddle.

67. Securing in Position.—The weight of a large planer is sufficient to hold it in position on the foundation while resting on the adjusting blocks. Medium- and small-sized planers are usually set directly on the foundation and leveled by putting shims, or thin pieces of metal, wood, or paper, under the supports. When medium-sized planers are located, holes are sometimes made in the supporting surface so that round pins half an inch or more in diameter can be inserted close to the bed or legs to prevent any possible movement.

Small planers provided with legs or bases have holes drilled through the flanges of the legs or bases through which lag screws or expansion bolts pass and prevent end or side motion. They should not be drawn down tight or they may spring the machine. Many long planers are set permanently on adjusting blocks so that they may be tested and leveled as often as may be necessary to keep them level and in line.

The table of a planer should be tested lengthwise with a straightedge. If it is not straight, it will plane the work concave or crowning.

68. Small- and medium-sized planers are shipped with all their parts in place, but need as careful, though not as much, attention in erection as do the larger sizes, which must be assembled on their foundations. It is usually sufficient to drive wedges under the legs until the table is level. The cross-rail is then tested to see that it is parallel to the top of the table. If it is not parallel, the table should be run back, and the cross-rail set parallel to the **V**'s, as described in Art. **62.** After this, a light cut should be taken over the table and the heads set to plane vertically.

In the case of very small planers, the beds are usually so stiff that very little, if any, adjusting is necessary when setting them up, all the adjustment being made by the manufacturer; but even in this case it is well to go through the entire series of tests, if accurate work is to be required from the machine.

69. Setting Heads.—The amount of accuracy required in setting the heads, either on a large or small planer, depends very largely on the character of the work to be done on the machine. If all the work will be simply roughing and surfacing, the zero mark *h*, Fig. 16, may be placed accurately enough by adjusting the head to any good try square and scribing the mark on the saddle; while if a large amount of angular work is to be done on the planer, all of the tests must be applied to see that the mark is accurately located.

ENGINE ERECTION

70. Equipment Necessary.—The manner of erecting an engine depends both on the equipment at hand and the style of the engine. Where medium-sized or heavy engines are to be erected, traveling cranes should be provided for handling the heavy parts, as they can accomplish the work much more quickly and easily than any other handling device, and also can command the entire erecting floor. The crane should have sufficient height of lift to place in position the highest parts of any machine built in the shop. Where very high work is to be erected, the base is sometimes set in a pit so that the highest parts will not come above the crane. This is especially the case in erecting vertical engines. Some shops making a specialty of vertical engines have two sets of traveling cranes, one above the other, the lower intended for handling the heavier pieces and the upper for handling the upper portion of the engine and the light pieces. If an engine should be so high as to interfere with the travel of the lower cranes, a crane may be set on each side of the engine before the cylinders are put up, so as not to cut off the rest of the erecting floor from the crane service while the high engine is in the shop. One advantage of having light, quick-motion traveling cranes placed well above the heavier cranes is that the upper cranes can lift light pieces above the lower cranes and carry them to any place on the erecting floor without interfering with the heavy work of the larger cranes.

71. All floors on which erecting is done should be firm and solid, to avoid any danger of the work being thrown out of line by settling when heavy parts are added. Before beginning work, the erecting floor should be cleared of all unnecessary obstructions and swept. The influence of the style of engine on the manner of erection will be brought out in the description of the horizontal and vertical types of engines. For the erection of small engines an iron-plate erecting floor on which the engine can be bolted down and tested is a great convenience.

HORIZONTAL STATIONARY ENGINES

72. Preparation of Bed.—The method of erecting a horizontal engine is not influenced greatly by the type of engine; that is, the work of erecting both Corliss and slide-valve engines is very similar. Before the engine bed is brought to the erecting floor it should be machined as far as possible, including the boring of the main bearing, if this is cast with the bed, and the scraping of the guides. The guides are usually scraped to a special surface plate, or to the crosshead itself, before the work is brought to the erecting floor, after which levels are placed on the guides and pillow-block bearings, and the bed is adjusted until it is level by means of wedges and leveling jacks.

73. Fitting Cylinder to Bed.—The cylinder is bolted to the bed or frame and a line or wire fastened to a piece of wood bolted to one of the studs in the end of the cylinder, as shown at *a*, Fig. 17. This line is carried through the cylinder, piston-rod stuffingbox, and guides, and fastened to the end of the frame in case the pillow-block is cast solid with the frame; or in the case of an engine in which the pillow-block is bolted to the frame, the line may be fastened to any suitable object, as, for instance, the angle plate and stick shown at *b*. The line should be set central with the bore of the cylinder at the back end by calipering from the inside of the cylinder to the line. An inside adjustable gauge or micrometer may be employed; but in most cases it is better to use a light pine stick like that illustrated in Fig. 18. The stick *a* is tapered at both ends and may have a pin *b* driven in at each end. The advantages of the stick in calipering are that it is lighter than the inside micrometer and is less affected by expansion and contraction than a metal gauge would be.

74. The line must also be brought central with the stuffingbox at the other end of the cylinder, by means of a stick similar to that shown in Fig. 18, but more quickly by use of the device illustrated in Fig. 19. This contrivance consists of a hardwood block *a*, which is turned to just fit the stuffingbox and has a $\frac{1}{4}$-inch hole *b* drilled in the center. The face of the block is

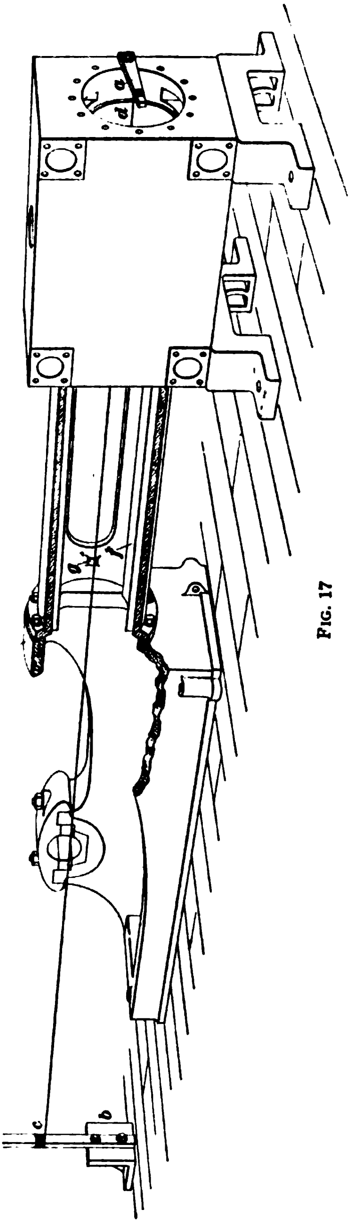

FIG. 17

turned square with the outside, and two center lines *c d* and *e f* are drawn across the face at right angles to each other. By sighting along the lines *c d* and *e f*, it is easy to determine when the line or wire *c d*, Fig. 17, is central with the stuffingbox. The angle plate *b* is adjusted until the line *c d* is central with the stuffingbox.

75. Lining Guides to Cylinder.—The guides may now be lined to the cylinder by measuring from the inside of the guides to the line at the top and bottom, as at *f*, Fig. 17, which will determine whether the line is central to the guides in a vertical plane. This test should be made at each end of the guides. In order to see whether or not the line is central horizontally, spots *g* are cast on the frame and faced off by the boring tool at the same time that the guides are bored.

Another and quicker method of lining the guides with the cylinder is to use a center block, as shown in Fig. 20. This block consists of a casting *a* that is turned to fit the inside of the guides. At the center there is a small hole *b* through which the line passes, and the lines *c d* and *e f* drawn at right angles to each other serve to locate the center line in its proper position, this being done in a manner similar to that described in Art. **74.** When the center block shown in Fig. 20 is used, the spotting plates *g*, Fig. 17, are not necessary.

76. Bringing Cylinder in Line With Guides.—If the cylinder is not in line with the guides, the joint between the cylinder and guides must be so fitted as to bring them in line. The amount of adjustment necessary may be determined by slacking off the nuts on one side and introducing pieces of sheet metal until the cylinder and guides are brought into exact alinement. After this, an amount equal to the thickness of the metal introduced may be removed from the other side of the end of the cylinder or guides. When very small, this amount is sometimes removed by filing or scraping; when greater, by machining.

FIG. 18

77. To machine parts so accurately that the cylinder of a large engine can be brought in line with the guides without fitting, has been found practically impossible and for this reason many builders place a loose ring or spacing piece between the cylinder and the guides, and in the case of a tandem compound engine, between the high-pressure and low-pressure cylinders. After the amount of adjustment necessary has been determined, this distance piece is taken out and the proper amount removed from the high side. When this method is followed, care must be taken to mark the distance piece so that it cannot be placed in a wrong position. To insure this, at least one of the stud or bolt holes uniting the parts should not be located according to the regular spacing system, so that the castings cannot be put together in any but the correct position. This may also be accomplished by using guides or dowel-pins.

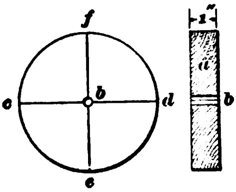

FIG. 19

78. Fitting Crank-Shaft.—After the cylinder and guides have been brought into perfect alinement, the crank-shaft is fitted. The outboard bearing may be very closely located by stretching a line through the shaft bearings at right angles to the lines through the cylinder and guides. The journals of the shaft should then be wiped clean and given a coat of marking material. The shaft should then be placed in its bearings with the lower half of the boxes in position and turned a few revolutions. The shaft is then lifted out of the bearings and the high spots scraped off with a half-round scraper. This operation is repeated until the shaft shows a good bearing in both the main pillow-block and the outboard bearing. After the lower half of each box is scraped, the upper halves may be put in place and fitted in like manner. The shaft is then taken from the bearings and the cranks pressed or shrunk on and keyed. The eccentrics and governor-driving device are also placed in position, after which the shaft is returned to its place.

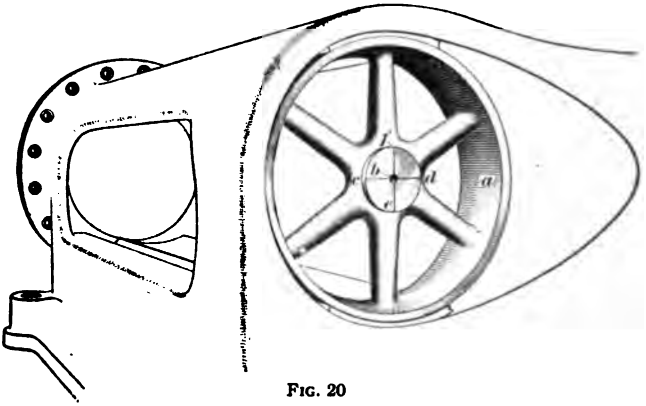

Fig. 20

79. To make sure that the crank-shaft is exactly at right angles to the center line of the engine, and also horizontal, the following course may be pursued: The crankpin *a*, Fig. 21, is brought up to the center line *c d* of the engine and a piece of wood *b* is fitted between the face of the crank *e* and the head of the crankpin *f*. A mark is made on this piece of wood in the middle, and this mark should coincide with the center line *c d*. If they do not coincide, the outer end of the crank must be moved until they do. The shaft is now turned a half revolution to bring the crankpin under the line at the other end of its travel, as shown by the dotted lines at *a'*. If the line on the stick *b* again coincides with the center line *c d*, the shaft is at right angles to the center line of the engine. To test the shaft to see whether it is level or not, a fine plumb-line may be hung vertically before the shaft and the crankpin *a* brought in contact with it at the upper portion of its revolution, and then tested again at the bottom of the revolution. If the crankpin just touches the line at both the top and the bottom, the shaft is horizontal.

80. Fitting Reciprocating Parts.—After the engine is lined up and the shaft is square and level, the reciprocating parts may be put in place. The piston, with its piston rod attached, is slipped into the cylinder and the crosshead into the end of the guides. The piston rod passes through the bushing in the head of the cylinder and is secured to the crosshead. These parts should be tested as they are put in place, to see that they line up properly. Some makers use a crosshead of such a pattern that the line *c d*, Fig. 17, may be carried through it and used in testing the crosshead to see that it lines up properly. After the crosshead and piston rod are in place, the connecting-rod may be put on. Before any of the surfaces that are to slide or move on one another are placed in contact, they should be well oiled. The oiling devices are put in place as fast as the parts are ready for them.

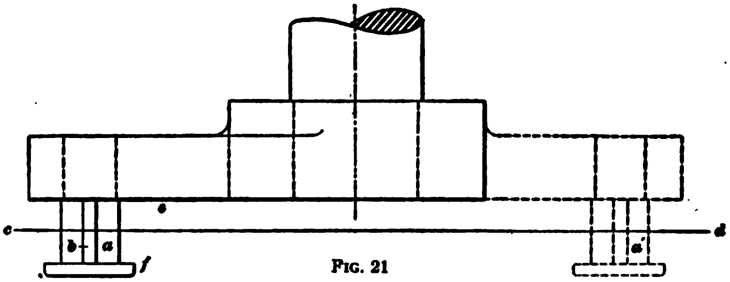

FIG. 21

81. As the control of the movements of the engine depends on the governor, consequently, great care should be taken to see that there is no danger whatever of its sticking or failing to act. To insure its perfect operation, the governor should be assembled separately and belted up so as to run at about its normal speed. The gears should be fitted so as to run as quietly and as smoothly as possible, and the dashpots, weights, and all parts properly adjusted during this preliminary run. It is usually best to run the governor one or two days in this way. After the governor has been fully adjusted, it may be taken down and placed on the engine. If the engine is a Corliss engine, the dashpots are responsible for the closing of the valves, and hence they should be assembled and tested before being placed on the engine. Shops building this class of engines usually have some device in which they can place a dashpot and run it for some time while adjusting it. After the dashpots are fully adjusted they are placed on the engine.

82. Devices for Oiling and Other Small Parts.—The oiling devices for the crankpin, eccentrics, crosshead, governor, and all other parts are put in place as fast as the parts are ready to receive them, and they should all be tested before steam is let into the engine.

83. Fitting Flywheel.—For small engines flywheels are made either solid or in halves. If made solid, the flywheel must be placed on the crank-shaft before this is lowered into the bearings. In some cases there is not room in the shop to put the flywheel in position, and the engine is assembled without the flywheel being placed on the shaft. Where it is possible, it is best to erect the flywheel with the engine. In erecting a large built-up flywheel, the hubs and hub flanges are placed on the shaft first. The arms and segments of the rim are then attached one at a time. By beginning the work on one side, the arms and sections of the rim may be attached to the hub flanges near the floor level, thus doing away with the necessity of raising them to any great height. After one arm and section of the rim are put in place, they may be lowered into the pit and the next one in order connected. This process may be continued until the wheel is completed. When the work is done under a traveling crane, it is usually more convenient to place each of the arms and segments at the top of the wheel and then lower them far enough to make room for the next.

84. Use of Dowel-Pins.—Whenever it is necessary to make the bed of an engine in sections, or when any parts require accurate alinement, they should be doweled together by drilling holes through the pieces and reaming them out with a taper reamer after the work is erected. After the holes are drilled and reamed, taper pins are fitted to them. These pins are usually given a taper of from $\frac{3}{8}$ to $\frac{3}{4}$ inch per foot. As each part is put in place, it should be clearly and distinctly marked by letters, figures, and lines, so that it may be easily returned to its position when erecting in the field. If the work is complicated, a record should be kept of the marks used so as to avoid confusion in the final erecting.

85. Lagging Steam Cylinders.—*Lagging* is the wooden, sheet-steel, or cast-iron covering put on steam-engine cylinders. It gives the cylinder a finished appearance and protects the inner covering, composed largely of asbestos, which is put on the cylinder to prevent the loss of heat. This non-conducting covering may be either applied in the shop previous to shipment, or in the field. The supports for the lagging are first secured to the cylinder, after which the asbestos mortar is prepared and applied to the cylinder. The mortar is spread evenly over the cylinder in such thickness as will not interfere with the lagging when attached. The cylinders are generally heated with steam when putting on the mortar, in order to dry it.

When cast-iron lagging is used, it is cast in sections and fitted to the cylinder. When sheet-steel lagging is employed, it is, when possible, cut to the right dimensions and rolled into a cylindrical form, or it is sheared to the proper size, if the cylinder is to be lagged square. The lagging sheets are finished by hand work. The screw holes in the sheets are generally drilled in a drilling machine. The sheet is clamped in place while the holes are marked off, after which the lagging supports are drilled and tapped. When the cylinder attachments have all been put in place and the cylinder tested, the lagging is put on.

86. Painting and Finishing Engine.—All rough places on the bed are smoothed off by chipping and filing before painting; in some cases the bed is given a coating of filling material that fills all depressions. After the bed has been filled and rubbed down with sandstone or sandpaper, it is painted. The specifications sometimes call for the testing and acceptance of the engine before painting.

87. Dismantling.—When the work is passed or pronounced correct by the superintendent or inspector, the man in charge of the erection of the engine oversees the taking down and prepares the parts for shipment. The lagging is usually removed and boxed. All small parts are also boxed. These boxes should be numbered and a careful record kept of their contents. The cylinder, in the case of large engines, is mounted on skids. All finished parts of the work are given a coating of some protective material, such as slushing oil or white lead and tallow that will prevent rusting. The bearings and fitted surfaces are boxed or covered with boards to protect them from injury. Crankpins and main shafts are sometimes wrapped with burlap or rope, and if large and finely finished, they may be lagged with wooden strips. In the case of comparatively small engines, the entire engine is sometimes placed on skids. If the machinery is to be shipped by rail the heavy parts of the load should come over the trucks, the lighter parts, boxes, etc. being located near the center of the car. All parts should be securely fastened, so that they cannot shift during shipment.

88. Foundation-Bolt Templet.—While the engine is being erected in the shop, a templet for locating the anchor bolts in the foundation is made. This templet should include the correct location of all bolts for securing the engine bed, cylinders, and outboard bearing to the foundation, and in the case of a large and complicated machine like a hoisting engine, should also include the bolts for the steam brake, steam reverse, drum-shaft bearings, etc. The templet is usually laid out from the drawing, after which all the dimensions should be checked by actual measurements of castings, to see that there is no discrepancy between the drawing and the casting. After the holes have been properly laid out, they are bored the same size as the anchor bolts. This templet is usually made of 1-inch white-pine lumber and must be thoroughly braced. The parts should be put together in a substantial manner with screws or bolts, or both, and also marked so that after being taken apart for packing and shipment the templet can be easily and accurately assembled at the foundation pit. Fig. 22 shows a plan of such a templet.

89. Foundations.—The foundations may be composed of masonry, brick, or concrete. Stone and brick should be laid in good cement mortar. The bolts may be built into the foundation or pockets may be left at the bottom for the washers and nuts, and holes left for introducing the bolts later. In some cases, these holes may be made by building wooden boxes or iron pipe into the foundation. In still other cases, the foundations are built with pockets near the bottom, and then the masonry or concrete built up solid, after which the bolt holes are drilled with a diamond drill. When the foundation is made of concrete it is usually better to build the bolts into it. In small work burlap may be wrapped around each bolt, forming a bunch, and these bunches are then raised along the bolts as the brickwork or masonry progresses, thus leaving clearance spaces around the bolts.

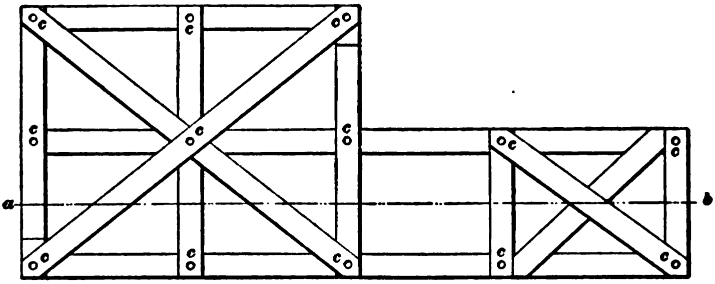

FIG. 22

90. The anchor bolts may be held down in a variety of ways. Sometimes a large washer is placed on the lower end of each bolt. In other cases a stirrup is formed at the lower ends of the bolts and pieces of railroad iron passed through these, as shown at *a*, Fig. 23. The pieces of iron may be long enough to extend through the stirrups of two or more bolts at once. The foundation-bolt templet *b* is supported on suitable blocking in a level position and rigidly braced to support the bolts. Sometimes it is necessary and best to suspend the templet by braces from overhead supports. The rails *a* should be wedged against the bottom of the stirrups *c* by driving wedges on top, as shown at *d*. To allow some adjustment of the bolts, a piece of pipe may be placed about them, as shown at *e*.

91. Appliances for Erecting Engine on Foundation. The engine is sometimes erected on the foundation by the man who did the erecting in the shop, where the erector has the advantage of all the shop tools and appliances, including cranes, special tools, etc. When the engine is shipped from the works, the man who is to go with it selects such tools as he requires. The tools needed vary greatly with the work and with the locality in which the engine is to be erected. Most modern power houses have traveling cranes in the engine rooms that can be used in erecting the engine or for any future repair work. In this case very few tools will be required. If the engine is to go into a region a long distance from any shop, as, for instance, a mining camp, the erector must take practically everything with him that he will require. Usually one or two hydraulic or ratchet jacks, a few screw jacks, and some pinch bars will be all of the larger tools necessary; a liberal stock of heavy ropes, wrenches, hammers, chisels, and other tools that may be needed should also be taken. If heavy parts must be hoisted some distance, it may be necessary to take a chain block or other hoisting devices. Sometimes it is conve-

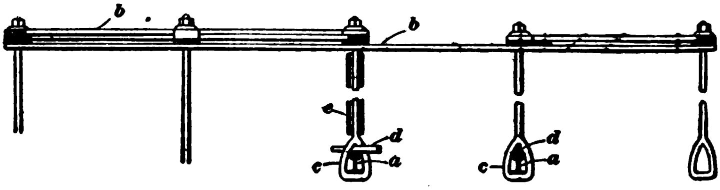

FIG. 23

nient to take a stock of rollers and blocking, but usually these can be obtained in the field.

92. Setting Engine on Foundation.—The engine bed and cylinder are placed on the foundation and bolted together. All the dowel-pins are fitted and the engine is lined up by stretching a line through the cylinder and beyond the crank, just as was done in the shop. The engine can be supported on iron wedges during this operation. The outboard bearing can be put in place and squared by means of the crank, as described in Art. 78. After the bedplate is properly located over the anchor bolts, the clearance spaces left around the bolts in the masonry should be filled with cement. This cement is mixed, the same as that used under the engine bed, as noted below. Enough water is added to the cement mixture so that it will flow readily into the holes. In large work with removable bolts, the cementing is not required. After the engine has been bolted together and lined up, the space between the bottom of the bedplate and the foundation may be filled with some suitable grouting. Usually Portland cement mixed in a proportion of 1 part of cement to 2 parts of sand is used; but if no cement is available melted sulphur, or a mixture of iron chips and sal ammoniac rammed in with a calking chisel, may be employed. When the grouting has hardened, the flywheel or pulley may be put in place and the caps over the bearings adjusted. All parts subjected to friction should be thoroughly oiled before being put into place, as an unoiled surface sometimes cuts during the first few revolutions before the oil reaches it through the oil hole. The piston, cross-head, connecting-rod, cylinder head, governor, valve gear, oiling devices, lagging, and piping are assembled in the order named.

93. The engine may now be turned a full revolution by hand to make sure that all is clear. Next, care should be taken to see that everything is in adjustment; then the steam may be turned on and the engine started very slowly. After the engine is started with steam, a thorough inspection of all working parts should be made and all the oiling devices properly adjusted. Any parts that have been left too loose may now be tightened to proper running fits, and any part that shows a tendency to heat should be examined and adjusted. After the engine has been running at full speed for some time, it may be belted up and kept at work while it is tested.

VERTICAL STATIONARY ENGINES

94. The method followed in erecting a vertical engine does not differ materially from that used in the horizontal engine; but as the parts are differently arranged, and in most cases some additional parts are required, a description showing the principal points of difference will be given. As a rule, it is more difficult to erect a vertical engine without the aid of cranes or hoists than a horizontal engine. Very large horizontal engines are frequently erected in the field without any hoisting tackle whatever, all the parts being moved on rollers and lined up by means of jack-screws. In the case of a vertical engine, it is usually necessary to rig a derrick, shear legs, or some hoist when in the field.

95. Work Necessary on Bed.—The bed *a*, Fig. 24, is leveled by means of wedges or erecting jacks, as in the case of a horizontal engine. The bearings for the crank-shaft may be scraped either before or after the guides are in place. Sometimes, to aid in scraping these bearings, a hollow cast-iron shaft is made of the same diameter as the crank-shaft. This is lighter than the crank-shaft and serves as a surface plate for scraping the bearings into line.

96. Fitting Guides and Cylinders.—The frames and guides *d* and *d'*, Fig. 24, are placed on the bed and temporarily bolted down. A center line along the center of the shaft is established by placing blocks across the bearings, as shown at *e*. A piece of tin is fastened to the center of each of these and a center line marked on it. A long straightedge is then laid across both blocks and a center line established. A line, as *f g h i*, is stretched through each cylinder. The line is secured at the bottom to a plank *j*, which is blocked or clamped to the bottom of the bedplate and has a hole in the center through which the line passes. At the upper end, above the cylinders, the line is secured to the plank *k*. The line passes over pulleys at *g* and *h*, and is kept taut by a heavy weight at *i*; a piano wire capable of standing a breaking stress of 400 pounds is usually used for this purpose, and the weight at *i* may vary from 100 to 200 pounds. This weight should be located so that no damage will be done if the wire should break. After the line is established, the guides and cylinders are adjusted to it. If desired, the weight at *i* may be hung under the cylinders in place of the plank *j*. To prevent vibration, the weight should be suspended in a vessel of water. Great care must be taken to see that the lines *f g* and *f′ g′* are the same distance apart, both top and bottom, and are in the same vertical plane.

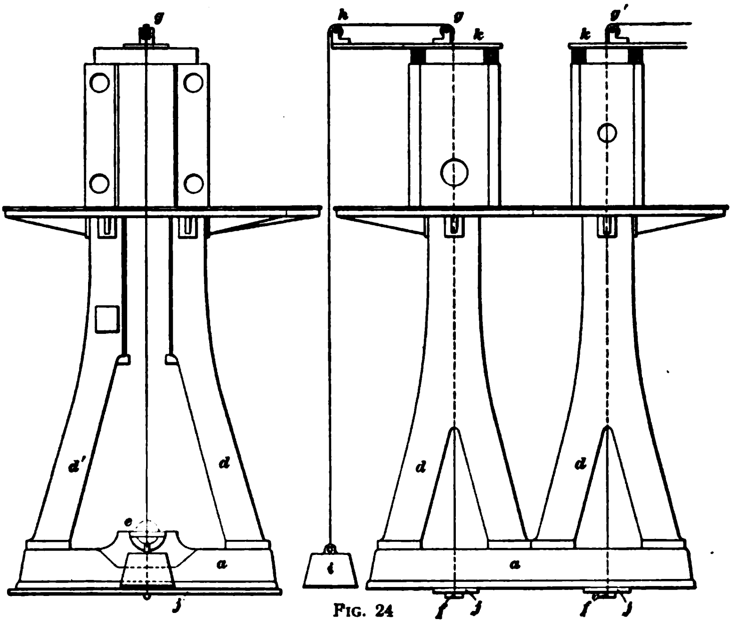

FIG. 24

If the cylinder does not come in line with the guides, packing pieces must be placed between the cylinder and the guides, as in the case of a horizontal engine, after which a sufficient amount must be dressed from the end of the cylinder or the intermediate piece, to bring the two into alinement. In measuring from the line to the cylinders, or from the line to the guides, a wooden measuring piece may be used, as described in Art. **73.** After the cylinders and guides are properly located, they are securely clamped in place, and the bolt holes for holding the uprights to the bed, the guides to the uprights, if the latter are made separate, and the cylinders to the guides, are reamed ready for the bolts. The holes for the dowel-pins are drilled and reamed and the pins fitted.

97. Placing Reciprocating Parts.—The placing of the reciprocating parts of vertical engines does not differ materially from that of horizontal engines, and the method of squaring the crank-shaft to the center line that is used in the horizontal engine can also be employed in the vertical engine.

98. Devices for Oiling and Smaller Parts.—In some cases, vertical engines are fitted with separate oiling devices for each bearing, while in other cases an oil tank is arranged at or near the cylinder from which pipes lead to the various bearings. Another system provides a reservoir with a pump, either attached to the engine or as a separate machine, which distributes the oil through a suitable arrangement of piping. All these devices are placed in position during erection. Since many parts of the engine are not accessible from the floor, some device must be provided by means of which the attendant can reach any part of the engine. For this purpose, platforms or floors are built around the engine at different elevations. The platforms are usually iron plates supported on brackets, and are reached by staircases leading from the floor of the engine room. The brackets and plates are all placed in position as the various parts of the engine are being assembled. Standards, which carry a hand rail, usually composed of brass or iron pipe, may be attached to the outer edges of the plates. Large vertical engines are often provided with hand or similar turning gear for turning the engine a portion of a revolution in starting or when fitting belts. They are also supplied with steam, vacuum, and revolution gauges, and a clock, which are attached to the engine frame, though they are not generally assembled in place until the engine is erected on its foundation; or they may be erected on a board entirely separate from the engine. The steam indicator is also attached to the engine.

99. Dismantling.—After an engine has been erected and tested, it is dismantled in a manner similar to that used in taking down large horizontal engines, except that it must be done to a greater extent; that is, owing to the greater height of the vertical construction, more parts must be detached and shipped separately.

100. Permanent Erection.—The erection of a vertical engine on the foundation does not differ materially from that of a horizontal engine, except that in some cases no line is stretched through the engine when it is erected on the foundation, bolts and dowel-pins being depended on entirely for bringing the parts into line. In erecting a vertical engine, the bedplate must be carefully leveled and have a firm bearing before the other heavy parts are assembled on it.

INDEX

NOTE.—In this volume, each Section is complete in itself and has a Section number. This number is printed at the top of every page of the Section in the headline opposite the page number, and to distinguish the Section number from the page number, the Section number is preceded by a section mark (§). In order to find a reference, glance along the inside edges of the headlines until the desired Section number is found, then along the page numbers of that Section until the desired page is found. Thus, to find the reference "Annular cutters, §13, p14," turn to the Section marked §13, then to page 14 of that Section.

A

Accuracy of new lathes, §18, p44
  required in finished work, Limits of, §26, p11
Acme standard screw threads, Table of, §19, p18
  thread, §19, pp5, 17
  thread, Proportions of, §19, p17
  threads, Cutting, §19, p18
Adjustable hollow mill, §20, p11
  jaws for face plates, §15, p38
  pipe dies, §24, p31
  reamers, §13, p26
Adjustment, Poor, in machine, §18, p43
Adjustments of boring machine, Vertical and horizontal, §21, p22
A. L. A. M. standard thread, §19, p22
Alligator wrenches, §23, p13
Allowance for reaming, §13, p23
Allowances for different fits, §17, pp39, 40; §26, pp5, 6
  for press fits, §17, p36
  for shrink fits, §17, p38
  for sliding fits, §17, p32
Alloy steel for drills, §14, p4
Angle, Lathe, center, §15, p21
  Clearance, of drills, §13, p6
  Clearance, of side tools, §16, p11
  of clearance, §16, p5
  of keenness, §16, p5
  of rake, §16, p6
  of relief of drills, §13, p6
  of scraping edge of drills, §14, p33
  plate, §13, p47; §15, p41
Angles, Cutting, of boring tools, §16, p21
  of rake and clearance, Effect of height of tool on, §16, p10
Annular cutters, §13, p14
Appliances, Erecting tools and, §25, p1
  for erecting engine on foundation, §26, p46
  Laying out special, §24, p40
Apron, Details of, §15, p13
  Fitting lathe, §26, p23
Arbor, §15, p41
Assembling parts of lathe, §26, p23
  rim sections of flywheel, §26, p17
Attachment, Taper, §15, p18
Attachments for tapping, §19, p61
  for vertical boring mills, §21, p5
  Lathe, §15, p1
Automatic dies, §20, p12
  dies for thread cutting, §19, p57
  screw machines, §20, p41
Automobile Engineers, Table of standard screws of Society of, §19, p22
  threads, §19, p21
Axle lathe, §20, p51

B

Back gearing of drill press, §14, p3
  gears for lathe, Double and triple, §15, p8
  gears, Lathe, §15, p6
Ball-bearing drill spindle, §14, p4
  -peen hammers, §23, p1
  turning, §18, p25
Bars, Pinch, §25, p2
Bearing fit, §26, p1
  Boring spherical, §21, p32
  Fitting cylinder to engine, §26, p37
  Laying out engine, §24, p49
  Leveling planer, §26, p29
  Preparation of, for erecting engine, §26, p37
  Seasoning, machining, testing, and scraping lathe, §26, pp18, 19
  Supporting of planer, §26, p28

Bearing, Thrust, in headstock, §15, p11
  Work necessary on engine, §26, p48
Bench and vise work, §23, p1
  centers, §23, p5
  Inspection, §26, p12
  lathes, §20, p44
  Post, §23, p24
  with cast-iron legs and frame, §23, p21
  work, Tools used in, §23, p1
Benches, §23, p20
  General arrangement of, §23, p20
  Portable, §23, p23
Bends, Rope, §25, p47
Bent lathe tools, §16, p25
  -tail dog, Action of, in springing work, §18, p39
Blackwall hitch, §25, p47
Blades of forming heads, §20, p21
Block and tackle, §25, pp21, 22
  and tackle, Example of, §25, p23
  and tackle, Pull required to hold weight, §25, p23
  Chain, differential, §25, p24
Blocks and trestles, §25, p3
Blocking, Iron cylindrical, §25, p6
  up of lathes, §20, p51
  Chain, §25, p21
  Cylindrical, §25, p4
  Iron, §25, pp3, 4
  Parallel, §25, p4
  Screw-geared, §25, pp21, 25
  V, §13, p46
  Wooden, §25, p3
Blunt files, §23, pp36, 37
Bolt cutters, §19, p57
  cutters with lead screws, §19, p59
  holes, Laying out, for pipe flanges, §24, p44
Bolts and nuts, Table of United States standard, §19, pp9, 10
  Variations in diameter of standard, §19, p13
Boom of derrick, Placing, §25, p37
Bored holes, Measuring, §17, p41
Boring bar, Adjustment of cutters on, §17, p42
  bar, Boring tapers with slotted, §17, p46
  bar for spherical bearings, §21, p32
  bar, Horizontal floor mill, §21, p26
  bar, Shape of tools for, §17, p42
  bar, Spring of, §17, p43
  -bar support on boring machine, §21. p15
  bar, Taking cut with, §17, p42
  bar, Traveling-head, §21, pp15, 18
  bar, Vertical cylinder, §21, p31
  bar with traveling head, §16, p40
  bars for chucking, §16, p36
  bars, Single-end, §21, p15
  bars, Traveling, §21, pp15, 17
  bars, Type of, §16, p39
Boring bars used on centers, §21, pp15, 17
  bars with fixed cutters, §16, p39
  cone pulleys, §20, p28
  cut, Taking the, §17, p40
  Cylinder, §21, p28
  duplex pump cylinders, Fixture for, §21, p34
  engine cylinder, §17, p43
  fixture for gas-engine piston, §21, p35
  fixture, Hand-power, §21, p36
  fixtures, §21, p34
  for headstock and tailstock spindles, §26, p20
  -machine carriage, §21, p15
  machine, Corliss engine cylinder, §21, p29
  -machine head, Horizontal, §21, p14
  -machine table, §21, p15
  machine, Vertical and horizontal adjustments of, §21, p22
  machine, Vertical cylinder, §21, p31
  -machine work, Setting, and tools, §21, p20
  machine work, Setting by lining, §21, p21
  -machine work, Setting by tramming, §21, p20
  Machines employed in cylinder, §21, p29
  mill, Examples of work on vertical, §21, p7
  mill, Extension, §21, p4
  mill, Extension arms for table of vertical, §21, p11
  mill, Horizontal, §21, p1
  mill, Milling on, §21, p24
  mill, Rail head for, §21, p5
  mill, Rear column for, §21, p5
  mill, Setting up work on vertical, §21, p7
  mill, Small vertical, §21, p5
  mill, Vertical, §21, pp1, 2
  -mill work, §21, p1
  -mill work, Horizontal, §21, p13
  mills, Attachments for vertical, §21, p6
  on drill press or radial drill, §21, p36
  on horizontal boring machine, §21, p15
  operations, §17, p40
  Roughing and finishing cuts in, §17, p41
  small holes, §16, p23
  spherical bearings, §21, p32
  spherical surfaces, Portable device for, §21, p33
  tapers, §17, p44
  tapers with slotted bar, §17, p46
  tapers with traveling head bar, §17, p45
  tool, Height of, §16, p22
  tools, §16, p21
  tools for boring bar, Shape of, §17, p42
  tools, Holders for, §16, p23
  tools, Spring of, §16, p21
  with taper attachment and compound rest, §17, p44
Bottoming tap, §13, p36; §24, p27
Bowline knot, §25, p49

Box tool, Finishing, §20, p7
  tool, Roughing, §20, p6
Brass, Shape and setting of lathe tools for, §16, p11
Breakage of thread tools, §19, p35
Breast drills, §24, pp15, 20
Brick floors, §25, pp13, 16
Bridges in castings, §15, p48
British standard, or Whitworth, screw threads, Table of, §19, p20
  standard thread, §19, pp5, 19
  standard threads, Cutting, §19, p20
Broach, Square, §24, pp8, 9
Broaches, Use of several, in set, §24, p10
Broaching, Hand, §24, p8
  keyways, §24, p10
Bushing, Chipping piston-valve, §23, p30
Bushings, Drill and reamer, §14, p37
  Solid, for follower rest, §18, p20
Butt mill, §23, p50
  mills, §13, p14

C

Calculating change gears for screw cutting, §19, p24
  compound change gears, §19, p28
  cutting speeds, §17, p11
  simple change gears, §19, p27
Calculations, Examples of change-gear, §19, p29
Caliper tool, §18, p6
Calipering, Care in, §17, p30
  screw threads, §19, p46
Calipers, Use of, in measuring bored holes, §17, p41
  Use of, in turning, §17, p29
Cams, Turning, §18, p27
Cannon drills, §16, p34
Cap, Laying out large journal, §24, p45
Cape chisels, §23, pp24, 26
Carbon-steel drills, Speeds and feeds for, §14, pp53, p54
  -steel for drills, §14, p4
  -steel tools, Relative cutting speeds of metals with, §17, p9
  tool steel, §16, p12
Card, File, §23, p49
Care of files, §23, p49
Carriage, Boring-machine, §21, p15
  Lathe, §15, p4
Castings, Bridges in, §15, p48
  Patching chipped, §26, p24
  Precautions in regard to planer, §26, p28
Cast iron, Drill feeds used in, §14, p55
  iron, Feeds at which drills broke in, §14, p56
  -iron plate floors, §25, p16
  -iron solid mandrels, §15, p45
Cat head, §18, p18
Cat's paw, §25, p48
C clamp, §13, p47
Center and prick punches, §23, p2
  angle of lathe center, §15, p21
  countersinks, §13, p30
  drilling, §13, p5; §14, p29
  drilling with sensitive drill, §14, p11
  drills, §13, p35
  holes, Correctly formed, §17, p20
  holes, Drilling and reaming of, §17, p18
  holes, Making, §17, p19
  holes, Scraping, §18, p45
  marks, Changing, §17, p17
  punches, Special forms of, §23, p3
  Removal of live, §18, p50
  spiders, §15, p48
  Turning of live, §18, p47
Centering machines, §17, p17
  tools, §17, p19
Centers, Bench, §23, p5
  Boring bars used on, §21, pp15, 17
  Bridges for, in castings, §15, p48
  Care of, in polishing, §18, p33
  Forming, §17, p17
  Forms of lathe, §15, p21
  Grinding lathe, §18, p48
  Hardness of, §18, p46
  Heavy, §14, p42
  Lathe, §15, p19
  Laying out, for turning crank-shafts, §18, p26
  Lining lathe, §18, p51
  Locating, by cup center, §17, p16
  Locating, by dividers, §17, p14
  Locating, by hermaphrodites, §17, p15
  Locating, by surface gauge, §17, p15
  Necessity for true, §18, p44
  of circles, Locating, §24, p41
  of mandrels, Care of, §15, p43
  Placing work on, §17, p20
  Special, for hand lathe, §20, p55
  Testing location of, §17, p16
  Wear of, in taper turning, §18, p7
Chain block, Differential, §25, p24
  blocks, §25, p21
  tongs for pipe, §23, p12
Change-gear calculations, Examples of, §19, p29
  -gear stack, §19, p24
  gearing, Arrangement of, for screw cutting, §19, p25
  gears, Calculating compound, §19, p28
  gears, Calculating, for screw cutting, §19, p24
  gears, Calculating simple, §19, p27
  gears for metric threads, §19, p31
  -speed gear-box, §14, p8
Chasers, Changing, §20, p14
  Form of thread, §20, p14
Chasing threads on monitor lathe, §20, p24
Chattering, §16, p41

Chattering, Form of tool to prevent, §20, p19
  when filing, §23, p33
Chill, §22, p1
  Clear, §22, p2
  depth, Reading, §22, p2
  Mottled, §22, p2
  Total, §22, p2
Chilled casting, Testing, §22, p17
  iron, §22, p1
  iron, Built-up turning tools for, §22, p11
  iron, Cutting feeds for, §22, p15
  iron, Cutting-off tool for, §22, p10
  iron, Cutting speeds for, §22, p14
  iron, Drilling, §22, pp33, 36
  iron, Facing tool for, §22, p8
  iron, Grinding turning tools for, §22, p14
  iron, Grooving tool for, §22, p8
  iron, Holding tools for, §22, p12
  iron, Lip tools for, §22, p8
  iron, Machining, §22, p3
  iron, Material for tools for turning, §22, p7
  iron, Planing, §22, p33
  iron, Plug tool for, §22, p11
  iron, Roughing and finishing tools for, §22, p8
  iron, Selection of grinding wheels for, §22, p31
  iron, Solid turning tools for, §22, p7
  iron, Uses of, §22, p3
  roll, Cutting off riser head and necking, §22, p17
  rolls, Grinding, §22, p29
  rolls, Lathes for turning, §22, p5
  rolls, Necking, §22, p5
  rolls, Turning and grinding, §22, p3
  rolls, Turning solid, §22, p5
Chipping, §23, p24
  hammer, Pneumatic, §23, p31
  keyways, §23, p30
  large flat surfaces, §23, p28
  Methods of, §23, p26
  piston-valve bushing, §23, p30
  strip, §23, p29
Chisel and hammer, Holding, §23, p27
  steel, §23, p24
Chisels, Flat, cape, diamond, grooving, and side, §23, p24
  Forms of, §23, p24
Chuck for heavy drills, §13, p41
  for screw machine, §20, p4
  for small drills, §13, p40
  Quick acting roller, for drills, §13, p41
  Selection of, §15, p36
  Setting work in independent, §15, p33
  work, Flat-turret, §20, p39
Chucking, Boring bars for, §16, p36
  Example of, §15, p34
  on face plate, §15, p37
  reamer, §13, p21
Chucking reamer, Rose, §13, p21
  reamers, Fluted, §16, p35
  reamers, Shell, §16, p36
  tools, §16, p33
  tools, Starting true, §16, p37
Chucks, Advantages of different, §15, p35
  Automatic-reverse tapping, §13, p43
  Care in use of, §15, p36
  Classification of lathe, §15, p30
  Combination, §15, p31
  Independent, §15, p30
  Lathe, §15, p29
  Special, §15, p37
  Special, for toolmakers' lathe, §20, p43
  Universal, §15, pp30, 31
  Use of, §15, p36
Circle, Laying off subdivisions of, §24, p42
Circles, Locating centers of, §24, p41
  Reducing error when subdividing, §24, p44
  Table of factors for finding dimensions for dividing, §24, p43
Circular-cut files, §23, p33
  -cut files, Sharpening machines for, §23, p52
  forming tools, §20, p16
  parallels, §14, p39
Clamp, C, §13, p47
  Plain, §13, p45
  Polishing, §18, p34
  Pulley, §15, p40
  U, §13, p45
Clamping of rocker-arm to face plate, §15, p39
  regular work to face plate, §15, p38
Clear chill, §22, p2
Clearance, Angle of, §16, p5
  angle of drills, §13, p6
  angle of side tools, §16, p11
  Effect of height of tool on angle of, §16, p10
Closed passes, Templets for, §22, p22
  passes, Turning grooved rolls with, §22, p22
  planers, §26, p27
Coarse feeds, Advantage of, §17, p12
Coatings on which to make lines, §24, p33
Cold rolls, §22, p23
Collar-and-groove rolls, §22, p22
Collets, §13, p38
Combination chucks, §15, p31
  parting and nurling tool, §20, p9
Combined parting and forming tool, §20, p22
Compound change gears, Calculating, §19, p28
  -geared lathes, §19, p25
  rest, §15, p17
  rest, Boring with taper attachment and, §17, p44
  rest, Use of, in taper turning, §18, p9
Concave rolls, Turning, §22, p23
Concrete floors, §25, pp13, 15, 16
Cone mandrels, §15, p46

Cone pulleys, Boring, §20, p28
Corliss engine cylinder-boring machine, §21, p29
Corners, Filing into, §23, p46
Corrugated rolls, §22, p34
Corrugating machine, §22, p34
  the rolls, §22, p35
Counterbore, Double-ended cutter, §13, p30
  for light work, §13, p31
  Small, §13, p30
  Standard, §13, p31
Counterbores, §13, p30
  Interchangeable, §13, p32
Counterboring, §13, p5; §14, p29
  Bottom, §13, p32
Countershaft, Double-clutch, §20, p56
  Speed-lathe, §20, p56
Countersink, Combined reamer and, §13, p29
  Drill used as, §13, p28
  Guide, §13, p28
  Guide and collar, §13, p28
Countersinking, §13, p5; §14, p29
Countersinks, §13, p28
  Center, §13, p30
Cranes, §25, pp21, 28, 34
  Electric traveling, §25, p32
  Hand-operated, portable, §25, p28
  Hand-operated traveling, §25, p31
  Jib, §25, p28
  Kinds of traveling, §25, p31
  Trolley, §25, p30
Crank-arm, Laying out, §24, p46
  -driven drills, §24, pp15, 19
  -shaft, Fitting engine, §26, p39
  -shaft, Turning, §18, p26
  shafts, Laying out centers for turning, §18, p26
Cross-feed, Graduated dial on, §19, p34
  -filing, §23, p43
  of the roll, §22, p24
  -peen hammers, §23, p1
  -rail, Squaring planer, §26, p32
  -slide tools, §20, p9
Crosshead, Laying out, §24, p47
Cup center, Locating centers by, §17, p16
Curved work, Scrapers for, §24, p4
Curves, Filing, §23, p45
Cut, Effect of force of, on spring, §18, p38
  Finishing, in cylinder boring, §21, p28
  Influence of diameter on resistance to, §17, p7
  Taking the, with lathe, §17, p22
Cuts, Finishing, on lathe, §17, p23
  Roughing, on lathe, §17, p22
Cutter, Horizontal floor mill, §21, p26
  Pipe, §23, p15
Cutters, Adjustment of, on boring bar, §17, p42
  Annular, §13, p14
  Bolt, §19, p57
Cutters, Bolt, with lead screws, §19, p59
  Forms of spot-facing, §13, p34
  Single-tool and double-tool annular, §13, p14
Cutting Acme threads, §19, p18
  angles of boring tools, §16, p21
  British standard threads, §19, p20
  double threads, §19, p37
  feeds for chilled iron, §22, p15
  inside threads, §19, pp39, 41
  inside threads, Tools for, §19, p40
  multiple threads, §19, p37
  off pipe, §20, p61
  off riser head and necking chilled roll, §22, p17
  -off tool, §16, p18
  -off tool for chilled iron, §22, p10
  screw threads, §19, p32
  screw threads on lathe, §19, p24
  speed, Conditions governing, §17, p2
  speed, Effect of kind of metal on, §17, p3
  speed, Factors limiting, §17, p2
  speed, Finding revolutions for desired, §17, p12
  speed for finishing cuts, §17, p6
  speed for radial facing, §18, p14
  speed for roughing cuts, §17, p6
  speed, Limit of, §17, p2
  speed of lathe tools, §17, p1
  speed, Relation of tool steel to, §17, p8
  speeds and feeds for drills, §14, p46
  speeds, Average, §17, p8
  speeds, Calculation of, §17, p11
  speeds for chilled iron, §22, p14
  speeds, Relative, of metals with carbon-steel tools, §17, p9
  speeds, Use of low, §17, p8
  square threads, §19, p16
  thread, §24, p24
  threads by hand, §19, p56
  threads, Precautions in, §19, p46
  tool, United States standard thread, §19, p11
  tools, Forms of, §16, p12
  tools, Steels used for, §16, p12
  tools, Theory of, §16, p1
  triple threads, §19, p38
  V threads, Tool for, §19, p5
Cylinder boring, §21, p28
  Boring an engine, §17, p43
  -boring bar, Vertical, §21, p31
  -boring machine, Corliss engine, §21, p29
  -boring machine, Vertical, §21, p31
  boring, Machines employed in, §21, p29
  Bringing engine, in line with guides, §26, p39
  Fitting engine, to bed, §26, p37
  Lining guides to engine, §26, p38
Cylinders, Fitting engine, §26, p48
  Fixture for boring duplex pump, §21, p34
  Lagging steam, §26, p43

3 //
24
7

Cylindrical blocks, §25, p4
  grinding machine, §22, p29
  iron blocking, §25, p6
  turning, Plain, §17, p14
  work, Fitting of, §17, p31

D

Deep holes, Drilling, §14, p24
Defects disclosed by inspection, Study of, §26, p14
Depth indicators, Drill-press, §14, p30
  of cut, Effect of variation in, on spring of tool, §18, p37
Derrick, §25, pp21, 34
  Dismantling, §25, p38
  Erecting mast of, §25, p36
  Erecting small, §25, p38
  Placing boom of, §25, p37
Diagonal filing, §23, p44
Diamond chisels, §23, pp24, 26
  point tools, Holders for, §16, p17
  -pointed hand tool, §16, p28
  -pointed inserted-blade tools, Grinding of, §16, p17
  -pointed tool, §17, p24
  -pointed tool, Grinding of, §17, p24
Die holders, §20, p8
  Adjustable pipe, §24, p31
  Spring, §20, p12
  stock and round dies, §24, p28
  stock and square dies, §24, p27
Dies and die holders, §20, p8
  Automatic, §20, p12
  Automatic, for thread cutting, §19, p57
  Hand, §19, p56
Differential chain block, §25, p24
Dismantling derrick, §25, p38
  engine, §26, p44
  vertical engine, §26, p51
Dividers, Locating centers by, §17, p14
Dogs, Equalizing, §18, p43
  Lathe, §15, p23
  Straight-tailed, §18, p41
Double-clutch countershaft, §20, p56
  -cut files, §23, pp33, 34
  hitch, §25, p47
  thread, §19, p2
  threads, Cutting, §19, p37
Dowel-pins, Use of, §26, p43
Draw-filing, §23, p46
Drifting, §24, p8
Drill, §13, p1
  and reamer bushings, §14, p37
  Angle and length of scraping edge of, §14, p33
  Center drilling with sensitive, §14, p12
  chuck, Quick acting roller, §13, p41
  feeds used in ordinary cast iron, §14, p56
Drill, Flat lipped, §13, p10
  Gear-driven radial, §14, p7
  grinding, §14, p31
  Heavy-duty high-speed, §14, p15
  High-speed sensitive, §14, p14
  lubricants, Application of, §13, p20
  lubricants, Provision for supplying, §13, p20
  Multiple-spindle, §14, p16
  point, Advantages of thin flat, §13, p8
  point, Grooved flat, §13, p8
  point, Testing form of, §14, p32
  points, Form of flat, §13, p6
  press, §13, p1
  press, Back gearing of, §14, p3
  press, Boring on, §21, p36
  -press depth indicators, §14, p30
  press, Driving of, §14, p2
  press, Feed-mechanism of, §14, p4
  press, Heavy, §14, p1
  -press spindle and head, §14, p3
  radial, Boring on, §21, p36
  Sensitive radial, §14, p12
  shank, Flat, §13, p9
  shank, Taper, §13, p16
  shanks, §13, p16
  shanks and sockets, Short, §13, p18
  shanks, Special forms of, §13, p19
  Simple radial, §14, p5
  socket for taper shanks, §13, p37
  socket, Key-grip, §13, p39
  socket, Pin-grip, §13, p38
  socket with setscrew, Straight, §13, p36
  sockets, §13, p38
  spindle, Ball-bearing, §14, p4
  Spindles, Universal adjustable, §14, p18
  Starting a twist, §16, p38
  Starting the, §14, p20
  Straight-fluted, §13, p12
  tang, §13, p16
  Teat, §13, p13
  Twisted, §13, p11
  Universal radial, §14, p7
  used as countersink, §13, p28
Driller, §13, p1
Drilling, §14, p20; §24, p14
  and tapping device, Safety, §13, p42
  Center, §13, p5; §14, p29
  center holes, §17, p18
  Center, with sensitive drill, §14, p12
  chilled iron, §22, p36
  crow, for ratchet drill, §24, p18
  deep holes, §14, p24
  duplicate pieces, §14, p34
  flanges with irregularly spaced holes, Jig for, §14, p35
  flanges with regularly spaced holes, Jig for, §14, p35

Drilling from the solid, §16, p38
  Holding work for, §13, p44
  holes to be tapped for pipe, §14, p25
  irregular surfaces, Jigs for, §14, p37
  jigs and fixtures, §14, p34
  Laying out for, §14, p20
  Lead holes for, §14, p22
  locomotive connecting-rods, §14, p38
  Lubricants for, §14, pp31, 52
  machine change-speed gear-box, §14, p8
  machine, Construction of, §13, p1
  machine, Driving gear of, §13, p2
  machine, Essential parts of, §13, p1
  machine, Feed motion of, §13, p3
  machine, Horizontal flange, §14, p19
  -machine table, §13, p44
  machine, Table of, §13, p4
  machine, Uses of, §13, p4
  machine, Vertical flange, §14, p19
  machines, Kinds of, §14, p1
  operation, Heavy, §14, p45
  parts together, §13, p48
  Preparation for, §14, p20
  Roller supports for, §14, p4
  Securing work for, §13, p44
  tools, §13, p6
  V supports for, §14, p40
  with jig, Example of, §14, p36
Drills, Angle of relief of, §13, p6
  Breast, §24, pp15, 20
  broke in cast iron, Feeds at which, §14, p56
  Cannon, §16, p34
  Carbon steel and alloy steel for, §14, p4
  Center, §13, p35
  Chuck for heavy, §13, p41
  Chuck for small, §13, p40
  Clearance angle of, §13, p6
  Crank-driven, §24, pp15, 19
  Cutting speeds and feeds for, §14, p46
  Electric, §24, p15
  Feeds and speeds for high-speed steel, §14, p55
  Flat, §13, p6; §16, p33
  Flexible-shaft, §24, þp15, 16
  for machine-screw taps, Table of tap, §14, p51
  for medium work, §14, p1
  for taps with U. S. standard threads, Table of tap, §14, p52
  for taps with V threads, Table of tap, §14, p50
  Forms of slot, §13, p12
  Front rake of, §13, p10
  to cut larger holes, Grinding, §14, p34
  Hand grinding of, §14, p31
  Holding devices for, §13, p36
  Holding of, §20, p15
  Lubrication of, §13, p20
Drills, Main features of, §13, p6
  Parallel sides for flat, §13, p9
  Pneumatic, §24, p15
  Portable, §24, p14
  Radial, §14, p5
  Ratchet, §24, pp15, 17
  Results of improperly formed flat, §13, p7
  Scotch, §24, pp15, 20
  Sensitive, §14, p11
  Speeds and feeds for carbon-steel, §14, pp53, 54
  Twist, §13, p11
  Twisted flat, §13, p10
  Use of slot, §13, p12
  were run when broken, Speeds at which, §14, p56
Drive fit, §17, pp31, 34
  fits, §26, p1
Driving, Correct method of, §18, p41
  gear of drilling machine, §13, p2
  mechanism, Placing of planer table and, §26, p31
  Spring due to method of, §18, p39
Duplicate pieces, Drilling, §14, p34

E

Earth floors, §25, pp13, 14
Electric drills, §24, p15
  hoists, §25, pp21, 27
  traveling cranes, §25, p32
  trucks, §25, p34
Emery cloth, Use of, in polishing, §18, p33
Engine, Appliances for erecting, on foundation, §26, p46
  bed, Laying out, §24, p49
  bed, Preparation of for erecting, §26, p37
  bed, Work necessary on, §26, p48
  crank-shaft, Fitting, §26, p39
  cylinder, Boring, §17, p43
  cylinder, Bringing in line with guides, §26, p39
  cylinder, Fitting to bed, §26, p37
  cylinder, Lining guides to, §26, p38
  Devices for oiling vertical, §26, p50
  Dismantling, §26, p44
  erection, §26, p36
  foundations, §26, p45
  guides and cylinders, Fitting, §26, p48
  lathe, §15, p1
  lathe and turret lathe, Comparison of, §20, p30
  lathe, Turret applied to, §20, p25
  oiling, Devices for, §26, p42
  Painting and finishing, §26, p44
  parts, Fitting reciprocating, §26, p41
  parts, Placing reciprocating, §26, p50
  Permanent erection of vertical, §26, p51

Engine, Setting, on foundation, §26, p47
Engines, Dismantling vertical, §26, p51
  Erecting horizontal stationary, §26, p37
  Erecting vertical stationary, §26, p48
Equaling files, §23, pp36, 37
Equalizing dogs, §18, p43
Erecting, §25, p1
Erecting engine on foundation, Appliances for, §26, p46
  Examples of, §26, p15
  floors, §25, pp12, 13
  floors, Foundations for, §25, p13
  floors, Kinds of, §25, p13
  gin pole, §25, p34
  horizontal stationary engines, §26, p37
  mast of derrick, §25, p36
  Shop and field, §25, p1
  small derrick, §25, p38
  Temporary, and temporary foundations, §25, p12
  tools and appliances, §25, p1
  vertical stationary engines, §26, p48
Erection, Engine, §26, p36
  of large wheels, §26, p15
  of lathes and planers, §26, p18
  of lathes, Systems of, §26, p18
  of planer in place, §26, p33
  of vertical engine, Permanent, §26, p51
  Shop, of planers, §26, p27
Error when subdividing circles, Reducing, §24, p44
Errors in lathe work, §18, p35
  in machine, §18, p43
  in screw cutting, §19, p45
Expanding mandrels, §15, p45
  mandrel, Special, §15, p47
Expansion reamer, §13, p27
Extension arms for vertical boring mill table, §21, p11
  boring mill, §21, p4
  for socket wrench, §23, p10
External thread, §19, p1
Eye splice, §25, pp41, 46

F

Face plate, Chucking on, §15, p37
  plate, Clamping regular work to, §15, p38
  plate, Clamping rocker arm to, §15, p39
  plate, Double, §14, p42
  plate, Use of paper on, §15, p40
  plates, §15, p19
  plates, Adjustable jaws for, §15, p38
Facing, §13, pp5, 14, 29
  arms, §18, p14
  head, Horizontal floor mill, §21, p26
  Radial, §18, p13
  Radial, of stationary work, §18, p14
Facing, Spot, §13, p5
  tool for chilled iron, §22, p8
  Tools used in radial, §18, p13
Factors for finding dimensions for dividing circles, Table, §24, p43
Fastening work on horizontal floor mills, §21, p26
Feed for bars, Roller, §20, p32
  Advantages of power, §14, p21
  -mechanism of drill press, §14, p4
  -motion, Lathe, §15, p4
  -motion of drilling machine, §13, p3
  of lathe tool, §17, p10
  of lathe tool, Relation of, to material, §17, p10
Feeds, Advantage of coarse, §17, p12
  and speeds for carbon-steel drills, §14, pp53, 54
  and speeds for high-speed steel drills, §14, p55
  and speeds, Grinding, §22, p31
  at which drills broke in cast iron, §14, p56
  Cutting, for chilled iron, §22, p15
  for drills, §14, p46
Female thread, §19, p2
Field erecting, §25, p1
File card, §23, p49
  face, Convexity of, §23, p39
  handles, Fitting wooden, §23, p39
  handles, Special, §23, p40
  Position of, for rotating work, §18, p31
  Pressure on, §23, p45
  steel, §24, p2
  teeth, Forms of, §23, p33
Filed work, Finishing, §23, p47
Files, Blunt, equaling, taper, hand, and safe-edge, or side, §23, pp36, 37
  Care of, §18, p30; §23, p49
  Circular cut, §23, p33
  circular-cut, Sharpening machines for, §23, p52
  Grading of, §23, p35
  Holding, §23, p40
  Increment-cut, §23, p33
  Pinning of, §23, p48
  Selection and care of, §23, p48
  Shapes of, §23, p36
  Single-, double-, and circular-cut, §23, pp33, 34
  Sizes of, §23, p35
  Table of characteristics and uses of, §23, p38
  Use of, §23, p32
Filing, §23, p32
  and scraping lathe work, §18, p30
  broad surfaces, §23, p44
  Chattering when, §23, p33
  Cross, §23, p43
  curves, §23, p45
  Diagonal, §23, p44

Filing, Draw, §23, p46
  Effect of oil on, §23, p47
  Even, on rotating work, §18, p32
  Height of work for, §23, p47
  into corners, §23, p46
  jigs, §23, p49
  machines, §23, p50
  Position of body when, §23, p47
  Purpose of, §23, p37
  Speed of work for, §18, p31
  stand, §23, p20
Filling and painting machines, §26, p26
Finished work, Limits of accuracy required in, §26, p11
Finishing and roughing cuts in boring, §17, p41
  box tool, §20, p7
  by grinding, §17, p33
  cut, Cutting speed for, §17, p6
  cut, Cylinder boring, §21, p28
  cuts for turning, §17, p28
  cuts, Lathe, §17, p23
  cuts, Rake for roughing and, §16, p8
  engine, §26, p44
  filed work, §23, p47
  lathe work, §18, p30
  polished surfaces, §18, p33
  tools for chilled iron, §22, p8
Fit, Drive, §17, pp31, 34
  Press, §17, pp31, 35
  Running or sliding, §17, pp31, 32
  Shrink, §17, pp31, 37
  Wringing, §17, p31
Fits, Allowances for different, §17, pp39, 40; §26, pp5, 6
  Allowances for press, §17, p36
  Allowances for shrink, §17, p38
  Allowances for sliding, §17, p32
  Assembling shrink, §17, p38
  Classification of, §26, p1
  Drive, press, and shrink, §26, p1
  Heating work for shrink, §26, p8
  Influence of temperature on, §26, p5
  Kinds of, §17, p31
  Shrink, §26, p7
  Shrink, on large guns, §17, p39
  Sliding, running, free, and bearing, §26, p1
  Straight and taper press, §26, pp4, 6
  Straight press, §17, pp35, 36
  Taper press, §17, pp35, 36
Fitting and finishing by grinding, §17, p33
  and inspection of work, §26, p1
  cylindrical work, §17, p31
  engine crank-shaft, §26, p39
  engine cylinder to bed, §26, p37
  flywheel, §26, p42
  guides and cylinders, §26, p48
  headstocks and tailstocks, §26, pp19, 21
Fitting keys, §24, p12
  lathe apron, §26, p23
  lathe saddles, §26, p22
  of taper, §18, p11
  reciprocating parts of engine, §26, p41
Fixture, Boring, for gas-engine piston, §21, p35
  for boring duplex pump cylinders, §21, p34
  for turning spherical surfaces, §21, p11
  Hand-power boring, §21, p36
Fixtures, Boring, §21, p34
  Drilling, §14, p34
  for supporting and rotating work, §14, p[illegible]
Follower rest, §18, p19
Flange-drilling machine, Horizontal, §14, p1[illegible]
  -drilling machine, Vertical, §14, p19
  Laying out bolt holes for pipe, §24, p44
  with irregularly spaced holes, Jig for drilling, §14, p35
  with regularly spaced holes, Jig for drilling, §14, p35
Flat chisels, §23, p24
  drill, Lipped, §13, p10
  drill point, Advantages of thin, §13, p8
  drill point, Form of, §13, p6
  drill point, Grooved, §13, p8
  drills, §13, p6; §16, p33
  drills, Parallel sides for, §13, p9
  drills, Results of improperly formed, §13, p7
  drills, Twisted, §13, p10
  reamers, §16, p34
  scrapers, §24, pp1, 2
  surfaces, Chipping large, §23, p28
  turret, Construction of, §20, p34
  -turret chuck work, §20, p39
  turret lathe, §20, p28
Flexible-shaft drills, §24, pp15, 16
Floor mills, Horizontal, §21, p24
  mills, Setting and fastening work on horizontal, §21, p26
  pits, §25, pp12, 17
  pits, Construction of, §25, p18
Floors, Brick, §25, pp13, 16
  Concrete, §25, pp13, 16
  Earth, §25, pp13, 14
  Erecting, §25, pp12, 13
  Foundations for erecting, §25, p13
  Iron plate, §25, pp13, 16
  Kinds of erecting, §25, p13
  Scantling, §25, p13
  Tar concrete, §25, p15
  Wooden-block, §25, pp13, 16
  Wooden-plank, §25, pp13, 14
Fluted chucking reamers, §16, p35
  Straight-, drill, §13, p12
Flywheel, Assembling rim sections of, §26, p17
  Fitting, §26, p42
  Polishing rim of, §26, p17

Flywheel shaft, Lining up, §26, p15
Turning sides and face of rim, §26, p17
Follower rest, Solid bushings for, §18, p20
Force of cut, Effect of, on spring, §18, p38
Forged forming tools, §20, p15
turning tools, §16, p12
Forming heads, Blades of, §20, p21
heads, Special, §20, p20
tool, Combined parting and, §20, p22
tools, §16, p26
tools, Circular, §20, p16
tools, Forged, §20, p15
tools, Straight-faced, §20, p17
tools, Vertical-slide, §20, p18
Foundation-bolt templet, §26, p44
-bolt templet, and permanent foundation, §25, p13
Permanent, and foundation-bolt templet, §25, p13
Setting engine on, §26, p47
Foundations, Engine, §26, p45
for erecting floors, §25, p13
Temporary, and temporary erecting, §25, p12
Franklin Institute thread, §19, p5
Free fit, §26, p1
Front rake of drills, §13, p10

G

Gap lathe, §20, p49
Gas-engine piston, Boring fixture for, §21, p35
pipe, Table of, §14, p49
Gasoline-operated trucks, §25, p34
Gauge, Stop-, §20, p5
Testing inside threads with, §19, p43
United States standard thread, §19, p10
Gauges for laying out keyways, §24, p14
Use of, in measuring bored holes, §17, p41
Gear-box, Change-speed, §14, p8
-box, Index plate for, §19, p55
-box, Lathe, §19, p53
Geared head for lathe, §15, p25
head of turret lathe, §20, p30
Ratchet, screw lifting jacks, §25, p9
Gearing, Back, of drill press, §14, p3
Quick-change lathe, §15, p28
Gears, Calculating change, for screw cutting, §19, p24
Calculating compound change, §19, p28
Calculating simple change, §19, p27
Lathe back, §15, p6
Gin pole, Erecting, §25, p34
Gouge, Half-round, §23, p26
Gouges, §23, pp24, 26
Grading of files, §23, p35
Graduated dial on cross-feed, §19, p34
Grinding chilled rolls, §22, pp3, 29
Grinding, Drill, §14, p31
drills to cut larger holes, §14, p34
Fitting and finishing by, §17, p33
Hand, of drills, §14, p31
lathe centers, §18, p48
machine, Cylindrical, §22, p29
machine, Poole, §22, p29
of diamond-pointed inserted-blade tools, §16, p17
of diamond-pointed tool, §17, p24
of rolls, §22, p32
side tools, §16, p20
speeds and feeds, §22, p31
threading tool, §19, p7
Tool, §16, p29
tool, Effect of improper, §16, p32
turning tools for chilled iron, §22, p14
wheels for chilled iron, Selection of, §22, p31
Grooved rolls, Kinds of, §22, p19
rolls with closed passes, Turning, §22, p22
rolls with open passes, Turning, §22, p21
Grooving chisels, §23, pp24, 26
tool for chilled iron, §22, p8
Guides, Bringing engine cylinder in line with, §26, p39
Fitting engine, §26, p48
Lining, to engine cylinder, §26, p38
Guns, Building up large, §17, p39

H

Hack saws, Hand, §23, p6
saws, Power, §23, p6
Half-round end scrapers, §24, pp2, 5
round scrapers, §24, pp2, 5
Hammer and chisel, Holding, §23, p27
Chipping, pneumatic, §23, p31
handles, §23, p2
Hammers, §23, p1
Ball-, straight-, and cross-peen, §23, p1
Hand broaching, §24, p8
dies, §19, p56
file, §23, pp36, 37
grinding of drills, §14, p31
lathe, §20, p54
-operated cranes, Portable, §25, p28
-operated traveling cranes, §25, p31
-power boring fixture, §21, p36
reamer, Ordinary, §24, p21
reamers, §13, p22
reaming, Object of, §24, p21
screw machine, §20, p2
slide rest, §20, p56
tapping, §24, p24
taps, §19, p61
tools, §16, p28
tools, Theory of cutting tools applied to, §16, p1

Hand trucks, §25, p34
Handles, Fitting wooden file, §23, p39
  Hammer, §23, p2
  Special file, §23, p40
Hardness of centers, §18, p46
Head, Drill press spindle and, §14, p3
  Geared, of turret lathe, §20, p30
  Horizontal boring-machine, §21, p14
  Rail, for boring mill, §21, p5
Heads, Setting planer, §26, p35
Headstock, Geared, §15, p25
  Lathe, §15, p5
  Machining and fitting, §26, p19
  spindles, Boring for, §26, p20
  spindles, Taper holes in, §26, p24
Heating work for shrink fits, §26, p8
Hermaphrodites, Locating centers by, §17, p15
High-speed drill, Heavy-duty, §14, p15
  -speed, drills, §14, p4
  -speed sensitive drill, §14, p14
  -speed steel, §16, p13
  -speed steel drills, Feeds and speeds for, §14, p55
Hitch, Blackwall, §25, p47
  Double, §25, p47
  Timber, §25, p49
Hitches, Rope, §25, p47
Hoists and trucks, §25, p21
  Electric, §25, pp21, 27
  Pneumatic, §25, pp21, 26
Holder, Heavy inserted-blade tool, §16, p17
Holders, Die, §20, p8
  for boring tools, §16, p23
  for diamond point tools, §16, p17
  for turning tools, §16, p16
Holding and driving hollow rolls, §22, p25
  devices for drills, §13, p36
  files, §23, p40
  hammer and chisel, §23, p27
  lathe tools for hollow rolls, §22, p27
  scraper, §24, p5
  work for drilling, §13, p44
Hollow mill, Adjustable, §20, p11
  mill, Solid, §20, p11
  mills, §13, p14
  rolls, Holding and driving, §22, p25
  rolls, Lathe for turning, §22, p25
  rolls, Turning, §22, pp25, 28
Hook scrapers, §24, pp1, 4
  scrapers, Right-hand and left-hand, §24, pp1, 2, 4
Horizontal adjustments of boring machine, §21, p22
  boring-machine head, §21, p14
  boring mill, §21, p1
  boring-mill work, §21, p13
Horizontal floor mills, §21, p24
  floor mills, Arrangement of boring bar, cutter, and facing head, §21, p26
  floor mills, Setting and fastening work on, §21, p26
  stationary engines, Erecting, §26, p37
Horses, §25, p3
Hot iron, Size of rolls for working, §22, p24
  rolls, §22, p23
Housings, Setting of planer, §26, p30
Hubbing tool, §13, p15
Hydraulic jacks, §25, p10
  press, Portable, §26, p3
  press, Stationary, §26, p3

I

Increment-cut files, §23, p33
Independent chuck, Setting work in, §15, p33
  chucks, §15, p30
Index plate for gear-box, §19, p55
Indicator, Thread, §19, p51
Indicators, Drill-press depth, §14, p30
Inserted-blade parting tool, §16, p19
  -blade threading tools, §19, p8
  -blade tool holder, Heavy, §16, p17
  blade tools, Grinding of diamond-pointed, §16, p17
  blades, Reamers with, §13, p25
Inside threads, Cutting, §19, pp39, 41
  threads, Testing, §19, p42
  threads, Tools for cutting, §19, p40
  -thread tool, Setting, §19, p40
Inspection bench, rooms, and tags, §26, p12
  of lathes, §26, p25
  of raw material, §26, p10
  of ropes, slings, and lashings, §25, p40
  Study of defects disclosed by, §26, p14
  of work, §26, pp1, 10
  of work in progress, §26, p12
Inspector, Judgment required of, §26, p13
Internal thread, §19, p2
Inverted parting tool, §20, p21
Iron blocking, Cylindrical, §25, p6
Iron blocks, §25, pp3, 4
  Chilled, §22, p1
  plate floors, §25, pp13, 16

J

Jack, Adjustable-top leveling, §25, p7
  Ratchet lifting, §25, pp3, 9
  Screw, §13, p45
  Screw lifting, §25, p8
  Simple leveling, §25, p6
Jacks, §25, pp3, 6
  Hydraulic, §25, p10
  Lifting, screw, geared, ratchet, §25, p9
  Screw, §25, p3

Jacks, Use of screw, §24, p41
Jaws, Adjustable, for face plates, §15, p38
  Spring of work from pressure of chuck, §15, p35
  Vise, §23, p18
Jib, cranes, §25, p28
Jig, Example of drilling with, §14, p36
  for drilling flanges with irregularly spaced holes, §14, p35
  for drilling flanges with regularly spaced holes, §14, p35
  Outside and inside, §14, p36
  Tapping, §24, p25
Jigs, Drilling, §14, p34
  Filing, §23, p49
  for drilling irregular surfaces, §14, p37
Journal cap, Laying out large, §24, p45

K

Keenness, Angle of, §16, p5
Keys, Fitting, §24, p12
  Provision for withdrawing, §24, p12
  Rectangular, §24, p12
  Round, §24, p13
  Taper of, §24, p13
  Woodruff, §24, p13
Keyways, Broaching, §24, p10
  Chipping, §23, p40
  Gauges for laying out, §24, p14
Knot, Bowline, §25, p49
  Overhand, §25, p44
  Square, §25, p49
Knots, Rope, §25, p47

L

Lagging steam cylinders, §26, p43
Large parallels, §25, p19
Lashings, §25, p39
Lashings, Inspection of, §25, p40
Lathe apron, Fitting, §26, p23
  Assembling parts of, §26, p23
  Axle, §20, p51
  back gears, §15, p6
  beds, Machining of, §26, p18
  beds, Seasoning, §26, p18
  beds, Testing and scraping, §26, p19
  carriage, §15, p4
  centers, §15, p19
  centers, Forms of, §15, p21
  centers, Grinding, §18, p48
  centers, Lining, §18, p51
  chucks, §15, p29
  chucks, Classification of, §15, p30
  Comparison of engine and turret, §20, p30
  cut, Taking the, §17, p22
  cuts, Roughing and finishing, §17, pp22, 23
  Cutting screw threads on, §19, p24
Lathe details, §15, p4
  dogs, §15, p23
  double back gears, §15, p8
  Engine, §15, p1
  feed-motion, §15, p4
  Flat turret, §20, p28
  for heavy work, §15, p23
  for turning hollow rolls, §22, p25
  Gap, §20, p49
  gear-box, §19, p53
  gearing, Quick-change, §15, p28
  Hand, or speed, §20, p54
  headstock, §15, p5
  headstocks and tailstocks, Machining and fitting, §26, pp19, 20, 21
  Lead of, §19, p26
  Main parts of, §15, p3
  monitor, Universal, §20, p23
  operations, §17, p1
  Plain taper-turning, §20, p46
  Pulley, §20, p54
  saddles, Fitting, §26, p22
  Setting up roll in, §22, p16
  Special shafting, §18, p20
  Special turret, for heavy work, §20, p26
  Speed-, countershaft, §20, p56
  Swing of, §15, p10
  tailstock, §15, p8
  thrust bearing in headstock, §15, p11
  tool, Conditions governing shape of, §16, p7
  tool, Effect of height on strength of, §16, p11
  tool, Feed of, §17, p10
  tool, Relation of feed of, to material, §17, p10
  Toolmakers, §20, p42
  tools, §16, p1
  tools, Bent, §16, p25
  tools, Conditions influencing angles of, §16, p7
  tools, Cutting speed of, §17, p1
  tools, Effect of feed on shape of, §16, p9
  tools, Effect of hardness of metal on shape, §16, p8
  tools, Effect of kind of metal on shape, §16, p7
  tools for brass, Shape and setting of, §16, p11
  tools, Holding, for hollow rolls, §22, p27
  tools, Relative cutting speeds of metals with carbon-steel, §17, p9
  tools, Shapes of, §16, p29
  tools, Spring of, §18, p35
  triple back gears, §15, p8
  Turret, §20, p1
  Turret applied to engine, §20, p25
  Two-spindle, §20, p49
  Wheel, §20, p53
  work, Errors in, §18, p35
  work, Finishing, §18, p30
  work, Polishing, §18, p33

Lathe work, Special, §18, p25
Lathes, Accuracy of new, §18, p44
  and lathe attachments, §15, p1
  Bench, §20, p44
  Blocking up of, §20, p51
  Compound-geared, §19, p25
  Erection of, §26, p18
  for turning chilled rolls, §22, p5
  Inspection of, §26, p25
  Simple-geared, §19, p25
  Special chucks for toolmakers', §20, p43
  Special forms of turret, §20, p25
  Systems of erection of, §26, p18
  Types of turret, §20, p2
  When to use turret, §20, p41
Laying off subdivisions of circle, §24, p42
  out, §24, p31
  out appliances, Special, §24, p40
  out bolt holes for pipe flanges, §24, p44
  out centers for turning crank-shafts, §18, p26
  out crank-arms, §24, p46
  out crosshead, §24, p47
  out, Divisions of, §24, p32
  out ends for small rods, §24, p52
  out engine bed, §24, p49
  out, Examples of, §24, p41
  out for drilling, §14, p20
  out keyways, Gauges for, §24, p14
  out large journal cap, §24, p45
  out, Methods of, §24, p32
  -out plate for general work, §24, p37
  -out plate for heavy work, §24, p35
  -out plate for light work, §24, p34
  -out plate, Revolving, §24, p38
  -out tools, §24, p34
Layout, Preliminary, §24, p31
  Setting to, in boring machine work, §21, p21
Lead holes for drilling, §14, p22
  of lathe, §19, p26
  of thread, §19, p2
  -screw nut, Opening, §19, p50
  -screw pitch, Accuracy of, §19, p45
  -screw supports, §15, p9
  screws, Bolt cutters with, §19, p59
  screws, Straightening, §18, p22
Left-hand thread, §19, p2
Length of scraping edge of drill, §14, p33
Leveling jack, Adjustable-top, §25, p7
  jack, Simple, §25, p6
  planer bed, §26, p29
Lifting jack, Ratchet, §25, pp3, 9
  jack, Screw, §25, p8
  jacks, Screw, geared, and ratchet, §25, p9
Limits of accuracy required in finished work, §26, p11
Lines, Coatings on which to make, §24, p33
Lining engine cylinders with guides, §26, p39
Lining guides to engine cylinder, §26, p38
  lathe centers, §18, p51
  Setting by, in boring machine work, §21, p21
  up flywheel shaft, §26, p15
Lip tools for chilled iron, §22, p8
Live center, Removal of, §18, p50
  center, Turning of, §18, p47
  spindle, Lathe, §15, p11
Locating centers of circles, §24, p41
Locomotive connecting-rods, Drilling and reaming, §14, p38
Long splice, §25, pp41, 43
Lubricants, Application of drill, §13, p20
  for drilling, §14, p31
  for drilling, reaming and tapping, Table of, §14, p52
  Provision for supplying drill, §13, p20
Lubrication for thread cutting, §19, p51
  of drills, §13, p20

M

Machine reamers, §13, p21
  reaming, §14, p27
  -screw taps, Table of tap drills for, §14, p51
  -screw thread, §19, p1
  tapping, §19, p61
Machines, Straightening, §18, p20
Machining chilled iron, §22, p3
  headstocks and tailstocks, §26, p19
  lathe beds, §26, p18
Male thread, §19, p1
Mandrel press, §15, p43
  Special expanding, §15, p47
Mandrels, Care of centers of, §15, p43
  Cast-iron solid, §15, p45
  Cone, §15, p46
  Expanding, §15, p45
  Heavy cuts on light, §15, p44
  Nut, §15, p49
  Putting, in work, §15, p43
  Solid, §15, p41
Marking mixtures, §24, p6
  Prussian-blue, §18, p12
Marlinspike, §25, p41
Marrying rope strands, §25, p41
Masonry pit, Large, §25, p19
Mast of derrick, Erecting, §25, p36
Material, Inspection of raw, §26, p10
Materials used for ropes, §25, p39
Measuring bored holes, §17, p41
  screw threads, §19, p3
Methods of reaming, §14, p25
Metric threads, Change gears for, §19, p31
  thread table, §19, pp22, 23
Mill, Adjustable hollow, §20, p11
  Butt, §25, p50
  Solid hollow, §20, p11

Milling on boring mill, §21, p24
Mills, Hollow and butt, §13, p14
  Horizontal floor, §21, p24
Mixtures, Marking, §24, p6
Monitor lathe, Universal, §20, p23
Monkeywrench and pipe attachments, §23, p13
Morse tapers, §13, p17
Mottled chill, §22, p2
Multiple-spindle drill, §14, p16
  threads, §19, p3
  threads, Cutting, §19, p37

N

Necking chilled roll, §22, p17
  chilled rolls, §22, p5
Nurling tool, §20, p9
  tool, Parting and combination, §20, p9
Nut mandrels, §15, p49
Nuts, Table of United States standard bolts and, §19, pp9, 10

O

Oil, Effect of, on filing, §23, p47
Oiling, Devices for engine, §26, p42
  vertical engine, Devices for, §26, p50
Old man for ratchet drill, §24, p18
Open passes, Templets for, §22, p20
  -side planers, §26, p27
Origin of United States standard thread §19, p11
Ovals, Turning, §18, p28
Overhand knot, §25, p44

P

Painting and finishing engine, §26, p44
  Filling and, machines, §26, p26
Paper, Use of, on face plate, §15, p40
Parallel blocks, §25, p4
Parallels, §13, p46; §25, p4
  Circular, §14, p39
  Large, §25, p19
Parbuckle, §25, p49
Parting and forming tool, Combined, §20, p22
  and nurling tool, Combination, §20, p9
  tool, §16, p18; §20, p9
  tool, Inserted-blade, §16, p19
  tool, Inverted, §20, p21
Passes, Open and closed, §22, p20
  Templets for closed, §22, p22
  Templets for open, §22, p20
Patching chipped castings, §26, p24
Piano rest, §22, p7
Pinch bars, §25, p2
Pinning of files, §23, p48
Pipe attachments, Monkeywrench and, §23, p13
  Chain tongs for, §23, p12
  cutter, §23, p15
Pipe-cutting machine, §20, p57
  Cutting off, §20, p61
  dies, Adjustable, §24, p31
  flanges, Laying out bolt holes for, §24, p44
  stock, §24, p30
  Table of standard steam, gas, and water, §14, p49
  tapping, Drilling holes for, §14, p25
  Threading, §20, p61; §24, p29
  threads, §24, p27
  tongs, §23, p12
  vise, §23, p17
  wrench, Stillson, §23, p13
  wrench, Use of rope as, §23, p15
  wrenches, §23, p13
Piston, Boring fixture for gas-engine, §21, p35
  -valve bushing, Chipping, §23, p30
Pit construction for a definite line of work, §25, p18
  Masonry, §25, p19
  Wooden, §25, p21
Pits, Construction of floor, §25, p18
  Floor, §25, pp12, 17
Pitch, Effect of slight difference of, on fit, §19, p48
  of screw threads, Inaccuracy of, §19, p57
  of thread, §19, p1
  of threads, Expressing, §19, p4
Plain clamp, §13, p45
  rest, §15, p16
Planer bed, Leveling, §26, p29
  bed, Supporting of, §26, p28
  castings, Precautions in regard to, §26, p28
  cross-rail, Squaring, §26, p32
  driving mechanism, Placing of, §26, p31
  Erection of, in place, §26, p33
  heads, Setting of, §26, p35
  housings, Setting of, §26, p30
  Preparation for shipment of, §26, p33
  Securing, in position, §26, p34
  table, Placing of, §26, p31
Planers, Closed, and open-side, §26, p27
  Shop erection of, §26, p27
  Small, medium-sized, and large, §26, p27
Planing chilled iron, §22, p33
Plate, Angle, §15, p41
  Applying surface, §24, p7
  floors, Iron, §25, pp13, 16
  Laying-out, for general work, §24, p37
  Laying-out, for heavy work, §24, p35
  Laying-out, for light work, §24, p34
  Revolving laying-out, §24, p38
Plates, Angle, §13, p47
  Surface, §24, p6
Plug tap, §13, p36
  tool for chilled iron, §22, p11
Pneumatic chipping hammer, §23, p31

Pneumatic drills, §24, p15
  hoists, §25, pp21, 26
Pointing tool, §20, p8
Pole, Erecting gin, §25, p34
Polished surface, Finishing, §18, p33
Polishing, Care of centers in, §18, p33
  clamp, §18, p34
  lathe work, §18, p33
  of rim of flywheel, §26, p17
  Speed for, §18, p33
Poole grinding machine, §22, p29
Portable benches, §23, p23
  device for boring spherical surfaces, §21, p33
  drills, §24, p14
  hand-operated cranes, §25, p28
Post bench, §23, p24
Power feed, Advantages of, §14, p21
Preliminary layout, §24, p31
Press fit, §17, pp31, 35
  fits, §26, pp1, 4, 6
  fits, Allowances for, §17, p36
  fits, Straight, §17, pp35, 36; §26, p4
  fits, Taper, §17, pp35, 36; §26, pp4, 6
  Mandrel, §15, p43
  Portable hydraulic, §26, p8
  Stationary hydraulic, §26, p8
  Straightening, §23, p5
Pressure on file, §23, p45
Prick and center punches, §23, p2
Prussian-blue marking, §18, p12
Pulley clamp, §15, p40
  lathe, §20, p54
Pulleys, Boring cone, §20, p28
Pump cylinders, Fixture for boring duplex, §21, p34
Punches, Center and prick, §23, p2
  Special forms of center, §23, p3
Pusher, Tool, for chilled iron, §22, p8
Push-up for tool, §22, p11

Q

Quick-change gearing, Lathe, §15, p28

R

Radial drill, Boring on, §21, p36
  drill, Gear-driven, §14, p7
  drill, Sensitive, §14, p12
  drill, Simple, §14, p5
  drill, Universal, §14, p7
  drills, §14, p5
  facing, §18, p13
  facing, Cutting speed for, §18, p14
  facing of stationary work, §18, p14
  facing, Tools used in, §18, p13
Rail head for boring mill, §21, p [illegible]
Rake, Angle of, §16, p6
  Change of front top, to side top, §16, p10
Rake, Effect of height of tool on angle of, §16, p10
  for roughing and finishing cuts, §16, p8
  Front, of drills, §13, p10
  Top, of threading tools, §19, p36
Rapid-motion vise, §23, p16
Ratchet drill, Old man, or drilling crow, for, §24, p18
  drills, §24, pp15, 17
  Geared, screw lifting jacks, §25, pp3, 9
  thread, §19, pp5, 23
  wrenches, §23, p10
Raw material, Inspection of, §26, p10
Reamer and countersink, Combined, §13, p29
  bushings, Drill and, §14, p37
  Chucking, §13, p21
  Expansion, §13, p27
  Ordinary hand, §24, p21
  Rose chucking, §13, p21
  Stepped, §24, p22
Reamers, §13, pp11, 21
  Adjustable, §13, p26
  Care of, §13, p28
  Cutting faces of, §13, p23
  Flat, §16, p34
  Fluted chucking, §16, p35
  Hand, §13, p22
  Machine, §13, p21
  Number of cutting edges of, §13, p23
  Rose, §16, p35
  Roughing, §13, p24
  Shell, §13, p22
  Shell chucking, §16, p36
  Solid taper, §13, p24
  Stepped, §13, p25
  with inserted blades, §13, p25
Reaming, §14, p25; §24, p21
  Advantage of vertical, §24, p23
  Allowance for, §13, p23
  Care necessary in, §14, p26
  center holes, §17, p18
  holes in line, §24, p24
  locomotive connecting-rods, §14, p38
  Lubricants for, §14, p52
  Machine, §14, p27
  Methods of, §14, p25
  Rose, §14, p26
  stand, §23, p20
  Taper, §24, p22
  tapers, §17, p45
Reciprocating parts of engine, Placing §26, p50
  parts of engine, Fitting, §26, p41
Rectangular keys, §24, p12
Reducing error due to spring of tool, §18, p38
Relief, Angle of, of drills, §13, p6
Resetting threading tool, §19, p49

Resistance to cut, Influence of diameter on, §17, p7
Rest, Compound, §15, p17
  Follower, §18, p19
  Piano, §22, p7
  Plain, §15, p16
  Rise-and-fall, §15, p16
Rests, Hand slide, §20, p56
  Large diameter tool, §15, p10
  Steady, §15, p10; §18, p15
  Steady, for turret work, §20, p23
  Types of lathe, §15, p16
Returning worn rolls, §22, p24
Reversing mechanisms for screw cutting, §19, p24
Revolving laying-out plate, §24, p38
Right-hand thread, §19, p2
Riser head, Cutting off chilled roll, §22, p17
Rivett threading tool, §19, p51
Rocker-arm, Clamping of, to face plate, §15, p39
Rods, Laying out ends for small, §24, p52
Roll, Cross of the, §22, p24
  Setting up, in lathe, §22, p16
  Turning body of plain, §22, p17
Roller feed for bars, §20, p32
  supports for drilling, §14, p41
  turner, §20, p33
Rollers, §25, p2
Rolls, Collar-and-groove, §22, p22
  Corrugated, §22, p34
  Corrugating the, §22, p35
  Grinding chilled, §22, p29
  Grinding of, §22, p32
  Holding and driving hollow, §22, p25
  Hot and cold, §22, p23
  Kinds of grooved, §22, p19
  Lathes for turning chilled, §22, p5
  Returning worn, §22, p24
  Size of, for working hot iron, §22, p24
  Testing, §22, p32
  Testing, for straightness of surface, §22, p19
  Turning and grinding chilled, §22, p3
  Turning chilled solid, §22, p5
  Turning concave, §22, p23
  Turning grooved, with closed passes, §22, p22
  Turning grooved, with open passes, §22, p21
  Turning hollow, §22, pp25, 28
Rooms, Inspecting, §26, p12
Root diameter of thread, §19, p1
  of thread, §19, p1
Rope knots, bends, and hitches, §25, p47
  splicing, §25, p41
  Use of, as pipe wrench, §23, p15
Ropes, §25, p39
  Inspection of, §25, p40
Rose chucking reamer, §13, p21
  reamers, §16, p35
Rose reaming, §14, p26
Rotating tool, Turning with, §18, p22
Roughing and finishing cuts in boring, §17, p41
  and finishing cuts, Rake for, §16, p8
  box tool, §20, p6
  cuts, Cutting speed for, §17, p6
  cuts for turning, §17, p26
  cuts on lathe, §17, p22
  reamers, §13, p24
  tools for chilled iron, §22, p8
  tools, Shapes of forged, §16, p14
Round dies, Die stock and, §24, p28
  keys, §24, p13
  -nosed hand tool, §16, p28
  -nosed tools, Proper form of, §16, p14
Running fit, §17, p31
  fits, §26, p1

S

Saddles, Fitting lathe, §26, p22
Safe-edge file, §23, pp36, 37
Saws, Hand hack, §23, p6
  Power hack, §23, p6
Scantling floors, §25, p13
Scotch drills, §24, pp15, 20
Scraper, Holding, §24, p5
Scrapers, Flat, §24, pp1, 2
  for curved work, §24, p4
  Forms of, §24, p1
  Half-round, §24, pp2, 5
  Hook, §24, pp1, 2, 4
  Three-cornered, §24, pp2, 3
  Use of, §24, p1
Scraping, §24, p1
  center holes, §18, p45
  edge of drill, Angle and length of, §14, p33
  lathe beds, §26, p19
  lathe work, §18, p30
  Preparation of surface for, §24, p6
  turned cast-iron surfaces, §18, p32
Screw cutting, Arrangement of change gearing for, §19, p25
  cutting, Errors in, §19, p45
  cutting, Gear-box method of gearing lathe for, §19, p53
  cutting, Reversing mechanisms for, §19, p24
  -geared blocks, §25, pp21, 25
  jack, §13, p45
  jacks, §25, p3
  jacks, Use of, §24, p41
  lifting jack, §25, p8
  lifting jacks, Geared and ratchet, §25, p9
  machine, Chuck for, §20, p4
  machine, Hand, §20, p2
  machines, Automatic, §20, p41
  stop, §19, p34
  threads, §19, p1
  threads, Calipering, §19, p46

Screw threads, Cutting, §19, p32
threads, Cutting on lathe, §19, p24
threads, Fitting, on same lathe, §19, p49
threads, Inaccuracy of pitch of, §19, p57
threads, Measuring, §19, p3
threads, Table of Acme standard, §19, p18
threads, Table of British standard, or Whitworth, §19, p20
Table of Society of Automobile Engineers' standard, §19, p22
vise, §23, p16
Screws, Straightening lead, §18, p22
Scribers, §23, p4
Seasoning lathe beds, §26, p18
Selection of grinding wheels for chilled iron, §22, p31
Sellers thread, §19, p5
Semihigh-speed steels, §16, p13
Sensitive drill, Center drilling with, §14, p12
drill, High-speed, §14, p14
drills, §14, p11
radial drill, §14, p12
Setting by lining, in boring machine work, §21, p21
by tramming, in boring machine work, §21, p20
engine on foundation, §26, p47
of planer housings, §26, p30
of side tool, §17, p21
over tailstock for taper turning, §18, p3
planer heads, §26, p35
threading tool, §19, p7
to layout, in boring machine work, §21, p21
tools on boring machine, §21, p20
up roll in lathe, §22, p16
work on boring machine, §21, p20
work on horizontal floor mills, §21, p26
Shaft, Fitting of engine crank, §26, p39
Lining up flywheel, §26, p15
Shafting, Special lathe, §18, p20
Shank, Drill socket for taper, §13, p37
Flat drill, §13, p9
Straight drill, §13, p16
Taper drill, §13, p16
Shanks and sockets, Short drill, §13, p18
Drill, §13, p16
Special forms of drill, §13, p19
Shape of files, §23, p36
Sharp or V thread, §19, pp5, 6
Sharpening machines for circular-cut files, §23, p52
Shell chucking reamers, §16, p36
reamers, §13, p22
Shipment of planer, Preparation for, §26, p33
Shop erecting, §25, p1
erection of planers, §26, p27
Short splice, §25, pp41, 42
Shrink fit, §17, pp31, 37
fits, §26, pp1, 7
fits, Allowances for, §17, p38
fits, Assembling, §17, p38
fits, Heating work for, §26, p8
fits on large guns, §17, p39
Shrinking, Examples of, §26, p9
Sectional keys for, §26, p8
Side chisels, §23, pp24, 26
file, §23, pp36, 37
tool, Setting of, §17, p21
tools, §16, p20
tools, Clearance angle of, §16, p11
tools, Grinding, §16, p20
Simple-geared lathes, §19, p25
Single-cut files, §23, p33
-end boring bars, §21, p15
thread, §19, p2
Sizes of files, §23, p35
Slide rest, Hand, §20, p56
Sliding fit, §17, p31
fits, §26, p1
fits, Allowances for, §17, p32
Slings, §25, p39
Inspection of, §25, p40
Slot drills, Forms of, §13, p12
drills, Use of, §13, p12
Slotted bar, Boring tapers with, §17, p46
Small rods, Laying out ends for, §24, p52
Socket for taper drill shank, §13, p37
Key-grip drill, §13, p39
Pin-grip drill, §13, p38
Straight drill, with setscrew, §13, p36
wrench, Extension for, §23, p10
wrenches, §23, p10
Sockets, Drill, §13, p38
Short drill shanks and, §13, p18
Society of Automobile Engineers' standard screws, Table, §19, p22
Solid bushings for follower rest, §18, p20
hollow mill, §20, p11
mandrels, §15, p41
mandrels, Cast-iron, §15, p45
taper reamers, §13, p24
Special forming heads, §20, p20
Speed for polishing, §18, p33
lathe, §20, p54
-lathe countershaft, §20, p56
of work for filing, §18, p31
Speeds and feeds for drills, Cutting, §14, p46
and feeds for carbon-steel drills, §14, pp53, 54
and feeds for high-speed steel drills, §14, p55
and feeds, Grinding, §22, p31
at which drills were run when broken, §14, p56
Spherical bearings, Boring, §21, p32
surfaces, Fixture for turning, §21, p11

Spherical surfaces, Portable device for boring, §21, p33
Spiders, Center, §15, p48
Spindle and head, Drill press, §14, p3
  Ball-bearing drill, §14, p4
  Live, of lathe, §15, p11
Spindles, Boring for headstock and tailstock, §26, p20
  Taper holes in headstock, §26, p24
  Universal adjustable drill, §14, p18
Splice, Eye, §25, pp41, 46
  Long, §25, pp41, 43
  Short, §25, pp41, 42
Splices, Making, §25, pp42, 43, 46
Splicing rope, §25, p41
  tools, Rope-, §25, p41
Spot facing, §13, p5
  -facing cutters, Forms of, §13, p34
  -facing operations, §13, p34
  facing under side of flange, §13, p34
Spring die, §20, p12
  due to method of driving, §18, p39
  Effect of force of cut on, §18, p38
  Effect of weight of work on, §18, p38
  of boring bar and work, §17, p43
  of boring tools, §16, p21
  of lathe tools, §18, p35
  of tool, Reducing error due to, §18, p38
  of work, §18, p38
  of work from pressure of chuck jaws, §15, p35
  Sidewise, of thread tool, §19, p35
  tools, §16, p27
Springing work, Action of bent-tail dog in, §18, p39
Spotting of shaft for steady rest, §18, p18
Square broach, §24, pp8, 9
  dies, Die stock and, §24, p27
  knot, §25, p49
  thread, §19, pp5, 14
  thread tool, §19, p14
  threads, Cutting, §19, p16
Squaring cross-rail of planer, §26, p32
  ends, Tools used for, §17, p21
Stack, Change-gear, §19, p24
Stand, Filing, §23, p20
  Reaming, §23, p20
Standard bolts, Variations in diameter of, §19, p13
  tapers, §18, p2
  threads, Reason for selecting, §19, p11
Stationary engines, Erecting horizontal, §26, p37
Steady rest, §15, p10; §18, p15
  rest for turret work, §20, p23
  rest, Spotting of shaft for, §18, p18
Steam cylinders, Lagging, §26, p43
Steam, gas, and water pipe, Table of standard, §14, p49
Steel, Carbon tool, §16, p12
  Chisel, §23, p24
  File, §24, p2
  High-speed, §16, p13
Steels, Semihigh-speed, §16, p13
  used for cutting tools, §16, p12
Stepped reamer, §24, p22
  reamers, §13, p25
Stillson pipe wrench, §23, p13
Stock, Die, and round dies, §24, p28
  Die, and square dies, §24, p27
  Pipe, §24, p30
Stop-gauge, §20, p5
  Screw, §19, p34
  systems, For turret lathe, §20, p35
Straight-faced forming tools, §20, p17
  -peen hammers, §23, p1
  -tailed dogs, §18, p41
Straightening lead screws, §18, p22
  machines, §18, p20
  press, §23, p5
  small work, §18, p20
Strength, Effect of height of lathe tool on; §16, p11
Strip, Chipping, §23, p29
Studbolt wrench, §23, p12
Supporting of planer bed, §26, p28
Supports, Roller, for drilling, §14, p41
  Trunnion, §14, p44
  V, for drilling, §14, p40
Surface gauge, Locating centers by, §17, p15
  plate, Applying, §24, p7
  plates, §24, p6
  Preparation of, for scraping, §24, p6
Surfaces, Filing broad, §23, p44
Swing of lathe, §15, p10
Swivel vise, §23, p17

T

Table, Boring-machine, §21, p15
  Drilling machine, §13, p44
  of drilling machine, §13, p4
  Placing of planer, §26, p31
  Universal, §14, p7
Tackle, Block and, §25, pp21, 22
Tags, Inspection, §26, p12
Tailstock, Details of, §15, p11
  Lathe, §15, p8
  Setting over, for taper turning, §18, p3
  spindles, Boring for, §26, p20
  Thrust, §15, p12
Tailstocks, Machining and fitting, §26, p19
Taking the lathe cut, §17, p22
Tang, Drill, §13, p16
Tap, Bottoming, §13, p36; §24, p27

Tap drills for machine-screw taps, Table of, §14, p51
  drills for taps with U. S. standard threads, Table of, §14, p52
  drills for taps with V threads, Table of, §14, p50
  holes, Advantage of large, §19, p48
  Plug, §13, p36
  Taper, §13, p35
Taper attachment, §15, p18
  attachment and compound rest, Boring with, §17, p44
  drill shank, §13, p16
  file, §23, pp36, 37
  holes in headstock spindles, §26, p24
  of keys, §24, p13
  reamers, Solid, §13, p24
  reaming, §24, p22
  shank, Drill socket for, §13, p37
  tap, §13, p35
  Testing, when turning, §18, p11
  turning, §18, p1
  Turning and fitting of, §18, p11
  turning, Example of, §18, p10
  -turning lathe, Plain, §20, p46
  turning, Objections to setting over of dead center in, §18, pp7, 8
  turning, Position of tool for, §18, p11
  turning, Setting by notches, §18, p4
  turning, Setting by turning parallel to two diameters in, §18, p6
  turning, Setting over tailstock for, §18, p3
  turning, Setting with a model piece in, §18, p7
  turning, Use of compound rest in, §18, p9
  turning, Use of two feed-motions in, §18, p10
  turning, Wear of centers in, §18, p7
Tapered work, Threading, §19, p43
Tapers, Boring, §17, p44
  Boring, with slotted bar, §17, p46
  Boring, with traveling head bar, §17, p45
  Expressing and forming, §18, p1
  Methods of turning, §18, p2
  Morse, §13, p17
  Reaming, §17, p45
  Standard, §18, p2
Tapping, §13, p5; §14, p27; §19, p60
  Attachments for, §19, p61
  chucks, Automatic reverse, §13, p43
  device, Safety drilling and, §13, p42
  Drilling holes for pipe, §14, p25
  Hand, §24, p24
  hole, Correct size of, §14, p28
  holes, §19, p61
  jig, §24, p25
  Lubricants for, §14, p52
  Machine, §19, p61
  Methods of, §24, p24
Tapping smooth threads, §24, p26
Taps, §13, p35
  Effect of using dull, §19, p47
  Hand, §19, p61
  Holding of, §20, p15
  Number of, necessary, §24, p26
  Use of, §19, p60
  used, Forms of, §14, p27
Tar concrete floors, §25, p15
Teat drill, §13, p13
Teeth, Forms of file, §23, p33
Temperature, Influence of, on fits, §26, p5
Templet, Foundation-bolt, §25, p13; §26, p44
Templets for closed passes, §22, p22
  for open passes, §22, p20
Testing and scraping lathe beds, §26, p19
  chilled casting, §22, p17
  form of drill point, §14, p32
  inside threads, §19, p42
  location of centers, §17, p16
  of taper, §18, p11
  rolls, §22, p32
  rolls for straightness of surface, §22, p19
Thread, Acme, §19, p5; §19, p17
  British standard, §19, pp5, 19
  chasers, Form of, §20, p14
  cutting, §24, p24
  cutting, Automatic dies for, §19, p57
  cutting, Lubrication for, §19, p51
  cutting tool, United States standard, §19, p11
  Diameter of, §19, p1
  Double, §19, p2
  External, §19, p1
  Female, §19, p2
  Formal adoption of United States standard, §19, p13
  Franklin Institute, §19, p5
  gauge, United States standard, §19, p10
  Height of, §19, p1
  indicator, §19, p51
  Internal, §19, p2
  Lead of, §19, p2
  Left-hand, §19, p2
  Machine-screw, §19, p1
  Male, §19, p1
  Pitch of, §19, p1
  Point of, §19, p1
  Ratchet, §19, pp5, 22
  Right-hand, §19, p2
  Root diameter of, §19, p1
  Root of, §19, p1
  Sellers, §19, p5
  Shape of sharp or V, §19, pp5, 6
  Single, §19, p2
  Square, §19, pp5, 14
  Square, tool, §19, p14
  Table of metric, §19, pp22, 23

Thread tool, Correct height of, §19, p36
  tool, Sidewise spring of, §19, p35
  tools, Breakage of, §19, p35
  tools, Effect of using dull, §19, p47
  Triple, §19, p2
  United States standard, §19, pp5, 8
  V, §19, pp5, 6
  V, Perfectly fitted, §19, p46
  Whitworth, §19, p19
  Worm, §19, p21
Threading pipe, §20, p61; §24, p29
  tapered work, §19, p43
  tool, Grinding, §19, p7
  tool, Resetting, §19, p49
  tool, Rivett, §19, p51
  tool, Setting, §19, p7
  tools, Inserted-blade, §19, p8
  tools, Top rake of, §19, p36
Threads, Automobile, §19, p21
  Common forms of, §19, p5
  Change gears for metric, §19, p31
  Chasing, on monitor lathe, §20, p24
  Cutting Acme, §19, p18
  Cutting British standard, §19, p20
  Cutting, by hand, §19, p56
  Cutting double, §19, p47
  Cutting inside, §19, pp39, 41
  Cutting multiple, §19, p37
  Cutting screw, §19, p32
  Cutting screw, on lathe, §19, p24
  Cutting square, §19, p16
  Cutting triple, §19, p38
  Expressing pitch of, §19, p4
  Measuring screw, §19, p3
  Multiple, §19, p3
  Pipe, §24, p27
  Precautions in cutting, §19, p46
  Reason for selecting standard, §19, p11
  Screw, §19, p1
  Table of Acme standard screw, §19, p18
  Table of British standard, or Whitworth screw, §19, p20
  Tapping smooth, §24, p26
  Testing inside, §19, p42
  Tool for cutting V, §19, p5
  Tools for cutting inside, §19, p40
Three-cornered hand tool, §16, p29
  -cornered scrapers, §24, pp2, 3
Thrust, Tailstock, §15, p12
  bearing, Headstock, §15, p11
Timber hitch, §25, p49
Time required to take cut, Finding, §17, p12
Tongs, Chain, for pipe, §23, p12
  Pipe, §23, p12
Tool, Caliper, §18, p6
  Conditions governing shape of lathe, §16, p7
  Correct height of thread, §19, p36
Tool, Cutting-off, for chilled iron, §22, p10
  Diamond-pointed, §17, p24
  Effect of height on strength of lathe, §16, p11
  Effect of wear of, in turning, §18, p51
  Facing, for chilled iron, §22, p8
  Finishing box, §20, p7
  for cutting threads, §19, p5
  for turning, Position of, §17, p25
  Grooving, for chilled iron, §22, p8
  grinding, §16, p29
  Grinding threading, §19, p7
  Height of boring, §16, p22
  holder, Heavy inserted blade, §16, p17
  holders for turning tools, §16, p16
  Hubbing, §13, p15
  Inserted-blade parting, §16, p19
  Inverted parting, §20, p21
  Parting, §20, p9
  Parting, or cutting-off, §16, p18
  Plug, for chilled iron, §22, p11
  Pointing, §20, p8
  Position of, for taper turning, §18, p11
  rest, Large diameter, §15, p10
  Roughing box, §20, p6
  Setting inside-thread, §19, p40
  Setting of side, §17, p21
  Setting threading, §19, p7
  Sidewise spring of thread, §19, p35
  Spring of boring, §16, p21
  steel, Carbon, §16, p12
  steel, Relation of, to cutting speed, §17, p8
  Turning with rotating, §18, p22
Toolmakers' lathe, §20, p42
  lathe, Special chucks for, §20, p43
Tools and appliances, Erecting, §25, p1
  Bent lathe, §16, p25
  Boring, §16, p21
  Breakage of thread, §19, p35
  Built-up turning, for chilled iron, §22, p11
  Centering, §17, p19
  Chucking, §16, p33
  Circular forming, §20, p16
  Clearance angle of side, §16, p11
  Conditions influencing angles of lathe, §16, p7
  Cross-slide, §20, p9
  Drilling, §13, p6
  Effect of feed on shape of lathe, §16, p9
  Effect of hardness of metal on shape of lathe, §16, p8
  Effect of improper grinding of, §16, p32
  Effect of kind of metal on shape of lathe, §16, p7
  Effect of using dull thread, §19, p47
  for brass, Shape and setting of lathe, §16, p11
  for cutting inside threads, §19, p40
  for planing chilled iron, §22, pp33, 34
  for turning chilled iron, Material for, §22, p7

Tools, Forged forming, §20, p15
  Forming, §16, p26
  Forms of cutting, §16, p12
  Grinding of diamond-pointed inserted-blade, §16, p17
  Grinding side, §16, p20
  Grinding turning, for chilled iron, §22, p14
  Hand, §16, p28
  Holders for diamond point, §16, p17
  Holding, for chilled iron, §22, p12
  Holding lathe, for hollow rolls, §22, p27
  Inserted-blade threading, §19, p8
  Lathe, §16, p1
  Laying-out, §24, p34
  Lip, for chilled iron, §22, p8
  Nurling, §20, p9
  Proper form of round-nosed, §16, p14
  Rope splicing, §25, p41
  Roughing and finishing, for chilled iron, §22, p8
  Setting, on boring machine, §21, p20
  Shape of, for boring bar, §17, p42
  Shapes of forged roughing, §16, p14
  Shapes of lathe, §16, p29
  Side, §16, p20
  Solid turning, for chilled iron, §22, p7
  Spring, §16, p27
  Starting chucking, true, §16, p37
  Steels used for cutting, §16, p12
  Straight-faced forming, §20, p17
  Theory of cutting, §16, p1
  Theory of cutting tools applied to hand, §16, p1
  Theory of cutting tools applied to machine, §16, p4
  Top rake of threading, §19, p36
  Turning forged, §16, p12
  Turret, and their uses, §20, p5
  used for squaring ends, §17, p21
  used in bench and vise work, §23, p1
  used in radial facing, §18, p13
  Vertical-slide forming, §20, p18
Top rake of threading tools, §19, p36
Tramming, Setting by, in boring machine work, §21, p20
Traveling boring bars, §21, pp15, 17
  cranes, Electric, §25, p32
  cranes, Hand-operated, §25, p31
  cranes, Kinds of, §25, p31
  head bar, Boring tapers with, §17, p45
  -head boring bar, §21, p18
  head, Boring bar with, §16, p40
Trestles and blocks, §25, pp3, 6
Triple thread, §19, p2
  threads, Cutting, §19, p38
Trolley cranes, §25, p30
Trucks, §25, pp21, 34
Trucks, Hoists and, §25, p21
Trunnion supports, §14, p44
Turner, Roller, §20, p33
Turning a crank-shaft, §18, p26
  and fitting of taper, §18, p11
  Ball, §18, p25
  body of plain roll, §22, p17
  cams, §18, p27
  chilled iron, Material for tools for, §22, p7
  chilled rolls, §22, p3
  chilled rolls, Lathes for, §22, p5
  concave rolls, §22, p23
  crank-shafts, Laying out centers for, §18, p26
  Effect of wear on tool in, §18, p51
  Finishing cuts for, §17, p28
  grooved rolls with closed passes, §22, p22
  grooved rolls with open passes, §22, p21
  hollow rolls, §22, pp25, 28
  hollow rolls, Lathe for, §22, p25
  long work, §18, p15
  of live center, §18, p47
  operations, §17, p21
  ovals, §18, p28
  Plain cylindrical, §17, p14
  Position of tool for, §17, p25
  Roughing cuts for, §17, p26
  sides and face of rim of flywheel, §26, p17
  solid chilled rolls, §22, p5
  spherical surfaces, Fixture for, §21, p11
  Taper, §18, p1
  tapers, Methods of, §18, p2
  to a diameter, §17, p24
  tools, Built-up, for chilled iron, §22, p11
  tools for chilled iron, Grinding, §22, p14
  tools, Solid, for chilled iron, §22, p7
  tools, Forged, §16, p12
  tools, Holders for, §16, p16
  Use of calipers in, §17, p29
  with rotating tool, §18, p22
Turret and engine lathe, Comparison of, §20, p30
  applied to engine lathe, §20, p25
  applied to heavy work, §20, p25
  Construction of flat, §20, p34
  Flat-, chuck work, §20, p39
  lathe, §20, p1
  lathe, Action of, §20, p1
  lathe, Flat, §20, p28
  lathe for heavy work, Special, §20, p26
  lathe, Geared head of, §20, p30
  lathe, Stop systems for, §20, p35
  lathes, Special forms, §20, p25
  lathes, Types of, §20, p2
  lathes, When to use, §20, p41
  tools and their uses, §20, p5
  work, Steady rest for, §20, p23
Twist drill, Starting a, §16, p38

Twist drills, §13, p11
Twisted drill, §13, p11
  flat drills, §13, p10
Two-spindle lathe, §20, p49

U

U clamp, §13, p45
Undercutting, §13, p32
Under-cutting tool, Cleveland, §13, p32
United States standard bolts and nuts. Table of, §19, pp9, 10
  States standard thread, §19, pp5, 8
  States standard thread cutting tool, §19, p11
  States standard thread; Formal adoption, §19, p13
  States standard thread gauge, §19, p10
  States standard thread, Origin of, §19, p11
  States standard threads, Table of tap drills for, §14, p52
Universal chucks, §15, pp30, 31
  monitor lathe, §20, p23
  radial drill, §14, p7
  table, §14, p7
  vise, §13, p48
Use of paper on face plate, §15, p40

V

V blocks, §13, p46
  supports for drilling, §14, p40
  thread, §19, pp5, 6
  thread, Perfectly fitted, §19, p46
  threads, Table of tap drills for taps with, §14, p50
  threads, Tool for cutting, §19, p5
Vertical adjustments of boring machine, §21, p22
  boring mill, §21, p1
  boring mill, Large, §21, p2
  boring mill, Setting up work on, §21, p7
  boring mill, Small, §21, p5
  boring-mill table, Extension arms for, §21, p11
  boring mill work, Examples of, §21, p7
  boring mills, Attachments for, §21, p5
  cylinder-boring bar, §21, p31
  cylinder-boring machine, §21, p31
  engine, Devices for oiling, §26, p50
  engine, Permanent erection of, §26, p51
Vertical reaming, Advantage of, §24, p23
  -slide forming tools, §20, p18
  stationary engines, Erecting, §26, p48
Vise benches, §23, p20
  Drill, §13, p47
  jaws, §23, p18
  Pipe, §23, p17
  Rapid-motion, §23, p16
  Screw, §23, p16
  Swivel, §23, p17
  Universal, §13, p48
  work, §23, p1
  work, Tools used, §23, p1
Vises, §23, p16

W

Water pipe, Table of, §14, p49
Wear of tool, Effect of, in turning, §18, p51
Weight of work, Effect of, on spring, §18, p38
Wheel lathe, §20, p58
Wheels, Erection of large, §26, p15
Whitworth screw threads, Table of, §19, p20
  thread, §19, p19
Wooden-block floors, §25, pp13, 16
  blocks, §25, p3
  file handles, Fitting, §23, p39
  pit, §25, p21
  -plank floors, §25, pp13, 14
Woodruff keys, §24, p13
Worm thread, §19, p21
Worn rolls, Returning, §22, p24
Wrench, Monkey, and pipe attachments, §23, p13
  Socket, extension, §23, p10
  Stillson pipe, §23, p13
  Studbolt, §23, p12
  Use of rope as pipe, §23, p15
Wrenches, §23, p7
  Alligator, §23, p13
  Closed-end, §23, pp7, 9
  Double-end, §23, p9
  Offset, §23, p8
  Open-end, §23, p7
  Pipe, §23, p13
  Ratchet, §23, p10
  Single-end, §23, pp7, 8
  Socket, §23, p10
Wringing fit, §17, p31

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